Grain Starch Utilization Study

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Report of a Study Group Appointed by
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REPORT OF A STUDY GROUP APPOINTED BY THE
HON. OTTO E. LANG
MINISTER RESPONSIBLE FOR THE CANADIAN WHEAT BOARD

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REPORT OF A COMMITTEE APPOINTED BY THE HON.
OTTO E. LANG, MINISTER RESPONSIBLE FOR
THE CANADIAN WHEAT BOARD

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RESPONSIBLE FOR THE CANADIAN WHEAT BOARD,

HOUSE OF COMMONS, OTTAWA

SEPTEMBER, 1972

September 13, 1972.

The Honourable Otto E. Lang,
Minister Responsible for the
Canadian Wheat Board,
House of Commons,
Ottawa, Ontario.

Dear Mr. Lang:

On behalf of the Grain Starch Utilization Study Committee, which you appointed in October, 1971, I have pleasure in submitting to you their final report.

Our terms of reference were to review and assess the current capability of the Canadian industry to produce and market starch within the existing domestic and international environment, and to identify and recommend areas for specific action to improve this position. The data has been collected from diverse sources in Canada and abroad, many of which are not normally accessible. We believe that the report is the most complete study of the Canadian industry which has been undertaken, and trust that it will provide a useful insight into this segment of the grain economy.

The Committee acknowledges with gratitude the helpful assistance of your staff throughout the course of this study.

Respectfully submitted,

D.G. McNicol

D.G. McNicol, Chairman,
Grain Starch Utilization
Study Committee.

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HIGHLIGHTS

1. Canada's starch industry is comprised of manufacturers of starch from corn (3 companies), wheat (1), and potato (2). Production is concentrated in Ontario. Corn starch manufacturers account for more than 80 % of total production. (Page 6)

2. Principal products produced and major using industries of each are:

   (a) Starch - paper, corrugating, textile.
   (b) Dextrine - adhesives.
   (c) Glucose (corn syrup) - confectionery, ice cream.
   (d) Dextrose (corn sugar) - confectionery.

   All products are produced in a variety of grades. Grocery products are also produced by some firms. Co- and by-products including vital gluten from wheat starch production, corn oil and corn gluten feeds, are important economic factors in the industry. (Page 13)

3. Annual consumption of all products (excluding by-products) approximates 500 million pounds which is equivalent to 43 million cwt. of potatoes or 12 million bushels of corn, or 18 million bushels of wheat. Starch and glucose account for approximately one half and one third of total consumption. Under favourable circumstances, total volume could double by 1978. (Page 98)

4. About 80% of the Canadian demand is met from domestic production; the balance, mainly low cost starches, or grades or products which cannot be produced economically in Canada, are imported. Countries exporting to Canada include the U.S.A., Thailand, the Netherlands, and Brazil. (Page 33)

5. Canadian prices are established by the price of corn starch which, in turn, is related to the price of corn starch in the U.S. (Page 39).

6. Internationally, Canada holds a minor position with about 2% of world production. Major producers are the U.S.A. (40%) and E.E.C. (20%). Approximately 8% of production enters world trade, which is restricted by tariffs of 1¢ - 2¢ per pound. (Page 44)

7. Enzyme research has provided detailed information on the structure of starch and has led to the development of new types of glucose syrups, including fructose-containing syrup which can be substituted for sucrose. Further important developments in this area are expected. Another research area of great potential benefit would be the development of new starch products for the chemical industry.

8. Adjustment of quantity and quality of the starch component of field crops is possible by plant breeding methods. A decision to adjust the starch content would depend upon the long term economic position of starch relative to other components.

9. Contributions to the agricultural economy may be expected by adjusting the starch content of field crops. However, for a number of these crops, this would necessitate the development or improvement of techniques for separating and extracting starch from the other components.

10. Recommendations pertain to an increase in research activity, provision of incentives to Canadian production, assistance in the development of markets for existing and new products, and the establishment of an industry association. (Page 125)

SECTION I: INTRODUCTION

INTRODUCTION

This study was commissioned by the Grains Group, Department of Industry, Trade and Commerce, Ottawa, at the request of the Minister Responsible for the Wheat Board, the Hon. Otto E. Lang. It was prepared by a Committee consisting of Government and Industry officials having diverse backgrounds and experience.

The report is the first known attempt to define the Canadian starch industry and its problems. The Committee sincerely hopes that it will contribute in a small way to understanding the industry and its future success.

In addition to the contributions of those listed elsewhere in the report, the Committee wishes to thank Dr. Norman Tape and Dr. David Lees for their helpful assistance and kind cooperation.

SECTION II: TERMS OF REFERENCE

TERMS OF REFERENCE

The starch industry in Canada ranks as one of the more advanced starch industries of the world in terms of the variety of products produced, the production techniques employed, and the number of industrial applications. This advanced state of development has been achieved through the use and adaptation of conventional production processes which have been developed to extract starch from corn, wheat and potatoes.

The industry is dominated by manufacturers of starch from corn. For many years corn used in the industry had to be imported because of insufficient supplies of appropriate quantity and quality in Canada. However, in recent years Canadian corn production has increased and starch manufacturers have been able to obtain virtually all their requirements from domestic producers. Starch is also produced from wheat and potatoes grown in Canada. Thus the starch industry today could be said to be domestically self-sufficient in respect to raw materials.

Despite this trend to national self-sufficiency, it is recognized that Canada has the capability to produce vast quantities of starchy crops and to modify the composition of grains to improve starch yields. It is also recognized that technological advances could facilitate the development and expansion of markets at home and abroad for new and existing products, with subsequent increases in the utilization of Canadian grain.

To ensure that maximum advantage is taken of these potentialities, a Government-industry committee was directed to identify and assess opportunities for Canadian production and marketing of starch, starch derived products, and by-products, from Canadian grains, and to recommend areas for specific action.

Specific subjects suggested for investigation by this Committee are summarized as follows:

(1) Review of production, marketing and use of starch and starch-derived products in Canada and abroad.

(2) Review methods of manufacturing starch and its products.

(3) Identify trends in manufacture, product demand, product application, and competition from substitute products.

(4) Assess the strengths and weaknesses of foreign competition in starch manufacture. Include such factors as technological capabilities and resources, scale of operation, production costs, marketing environment, etc.

(5) Assess Canada's capability to produce a grain raw material for starch, starch derived products, and by-products which will improve the economies of starch and starch products manufacturers.

(6) If this capability (5) does not exist, identify the advances required to attain this objective - e.g. composition, yield and cost of raw material; transportation problems; manufacturing methods; by-product processing, etc.

(7) Recommend areas for specific action to improve Canada's competitive position or exploit identified opportunities.

SECTION III: THE CANADIAN STARCH INDUSTRY

THE CANADIAN STARCH INDUSTRY

A. BACKGROUND

History of the Industry

The origin of the starch industry in Canada can be traced to a mill established at Cardinal, Ontario, in 1858 to manufacture starch from corn. Cardinal is a small town on the St. Lawrence River between Cornwall and Brockville. In 1882, the first glucose (corn syrup) produced in Canada was also made at this plant.

By the turn of the century, four corn starch manufacturers were operating in Ontario but this number was reduced to two in 1906, through the merger of three firms. In 1969, a third corn starch operation was established at Collingwood, Ontario.

Potato starch manufacturing in Canada dates back to 1931 and marked the first occasion when starch was produced in this country from a product other than corn. During World War II, two plants operated in New Brunswick and one in Prince Edward Island. Today potato starch is manufactured in the Maritime Provinces at one plant located in Grand Falls, New Brunswick and a second establishment is producing at Vauxhall, Alberta. Development of this segment of the industry has been retarded by a chronic shortage of suitable raw materials at prices which can permit starch to be manufactured and sold in competition with starch from corn.*

Production of starch from wheat is restricted to a single plant at Thunder Bay, Ontario, which commenced operation in 1943 as part of the war effort.

At the present time, the starch industry is comprised of the following firms:

* see page 10.

The Canada Starch Company Limited

Head Office - Montreal. Plant-Cardinal, Ontario. Major products: corn starch, glucose, dextrose, dextrine. A subsidiary of CPC International Inc. U.S.A.

Industrial Grain Products Ltd.

Head Office - Montreal. Plant-Thunder Bay, Ontario. Major products: wheat starch, dextrine. A subsidiary of Ogilvie Flour Mills Ltd., which is owned by John Labatt Limited, London, Ontario.

National Starch & Chemical Co. (Canada) Ltd.

Head Office - Toronto. Plant-Collingwood, Ont. Major product: corn starch. A subsidiary of National Starch & Chemical Inc. U.S.A.

St. Lawrence Starch Co. Ltd.

Head Office - Port Credit. Plant-Port Credit, Ont. Major products: corn starch, glucose.

Valley Co-operative

Head Office - Grand Falls, N.B. Plant-Grand Falls, N.B. Major product: potato starch.

Pak-Well Products Ltd.

Head Office - Vauxhall, Alta. Plant-Vauxhall, Alta. Major product: potato starch.

Annual production of starch and starch-derived products by these firms is estimated at 500 million pounds in 1971. At this level of production, more than 200 million pounds of by-products would also be obtained. Total selling value of all products is estimated at $50-60 million annually.

Starch Production Processes

Starch is produced in Canada from three raw materials; corn, wheat and potatoes. The processes by which starch is obtained from these products have the commonality of separating starch from the other ingredients present in the raw material.

The proportions of these ingredients vary greatly between raw materials and even between different grades of raw material. A typical analysis of each is shown in table 1.

TABLE 1

TYPICAL ANALYSIS OF SELECTED
STARCH - BEARING PRODUCTS

	Corn	Wheat	Potato
Moisture	16.0%	12.0%	79.0%
Starch	60.0	55.3	15.0
Protein	9.0	13.2	2.0
Oil/Fat	4.0	2.1)	4.0
Other	11.0	16.6)	

Although the objectives for each process are the same, the methods employed to obtain starch are distinctly different. These differences arise from the forenoted differences in proportions of starch, and the ease with which it can be released and separated from the other components. A description of each process is provided in the following sections.

Starch From Corn

Production of starch and starch-derived products from corn constitute the most important segment of the starch industry in terms of physical volume and value of goods produced. It is estimated that products from corn account for 80% of the total production of the starch industry in Canada.

There are five grades of eastern corn described in the Canada Grain Act. The grades reflect different characteristics such as pounds per bushel, moisture, foreign material, and heat damage (which makes starch separation more difficult and reduces the yield). Taking cost and other pertinent factors into consideration, experience has shown that the most suitable grade of corn for starch manufacture is No. 2 Yellow Canada Eastern. The specifications of this grade are a minimum weight of 54 pounds per bushel, and maximum limits of 3% for cracked corn and foreign material, about 0.2% heat damage, and 5% total damage.

The typical corn kernel is enclosed in a hard fibrous covering or hull. Inside this hull is a mixture of gluten, starch and fibre, and the germ which contains most of the oil.

The manufacturing process begins with shelled corn which is first cleaned to remove pieces of cob and any foreign substance. The cleaned corn first goes into large vertical tanks where it is soaked or "steeped" for about 40 hours in warm water slightly acidified with sulphur dioxide. The dilute sulphurous acid prevents undesirable bacterial fermentation and helps extract the soluble matter from the corn. It also softens the hull and loosens the protein-starch-fibre complex so that the starch, gluten, fibre and germ can be separated from each other. When the steeping is finished, the first by-product is obtained by drawing off the steep water, which is then concentrated for use in livestock and poultry feeds, and certain industrial applications.

After steeping, the softened kernels are carried in a stream of water through attrition mills which free the germ and loosen the hull. The germ, which is lighter than the other parts of the kernel, is then separated by flotation or liquid cyclones. The separated germ is further washed and dried. Crude corn oil (the second by-product) is obtained from the dried germ either by pressure expellers or solvent extraction.

The balance of the wet mash which now contains starch, protein, and fibre, is further milled and the fibre portion is removed by washing through a series of shakers or screens.

Only the starch and gluten (protein) now remain to be separated. Since the gluten particles are lighter, they can be separated by centrifugal machines and liquid cyclones in which the starch can also be given a wash to remove the traces of soluble protein. The gluten obtained from this separation is generally dewatered and dried to form a gluten meal containing over 60% protein (by-product 3). This meal is then sold separately. The fibre and concentrated steep water are combined

into a gluten feed (by-product 4).

The final washed starch slurry may then be dried as prime starch, or treated in either the slurry or dry state with various reagents to make the specialized starches and dextrines required by industrial users. The washed starch slurry also constitutes the base material which is further treated to produce corn syrups, glucose, glucose solids, and dextrose.

Chart 1. is a summary flow-sheet of the wet milling process.

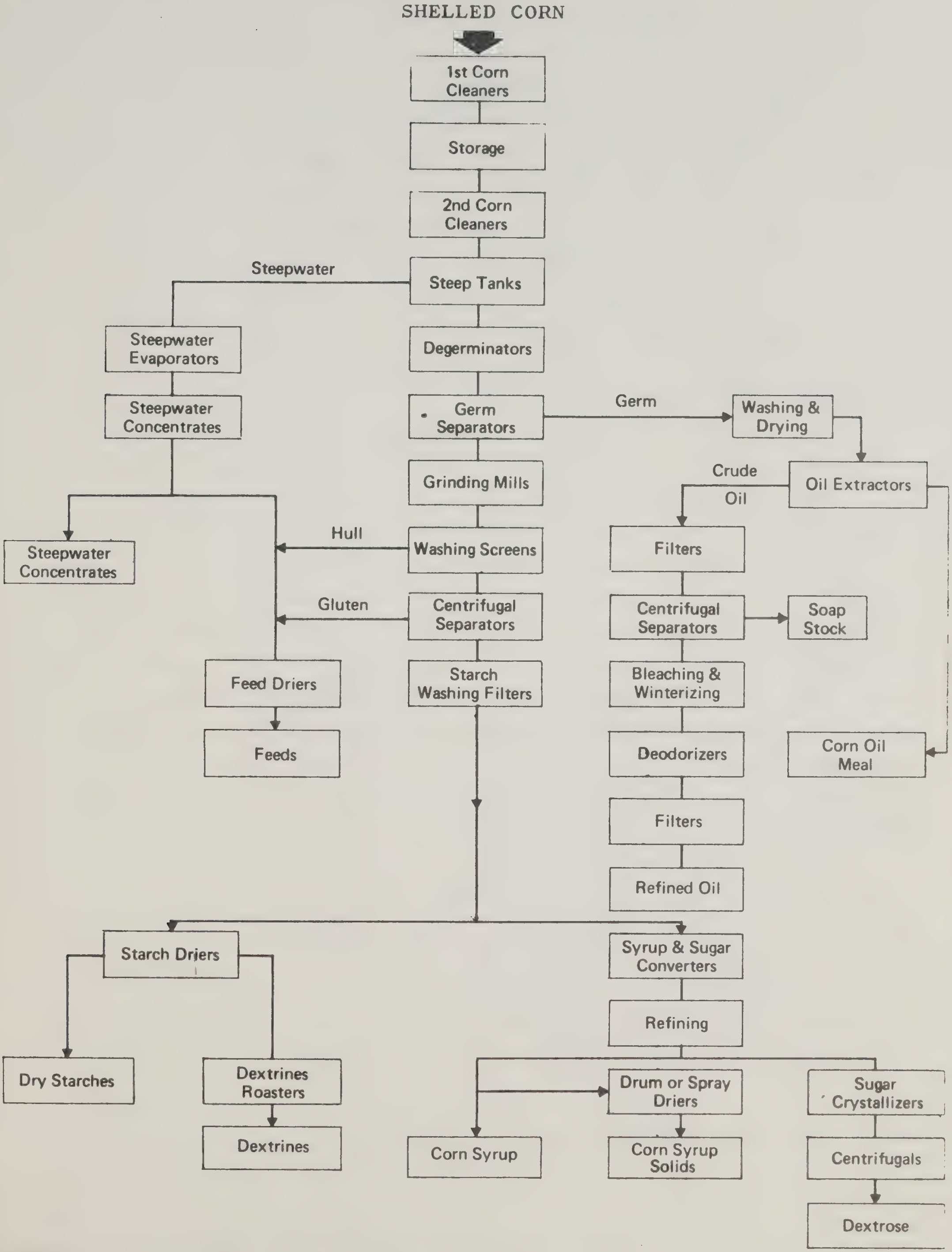
Starch from Wheat

The raw material for the manufacture of wheat starch and its co-products, vital and devitalized gluten, is wheat grain. The husk of the grain contains no worthwhile quantities of protein, fat or starch, and therefore it is the endosperm which is most important for starch manufacture. Since modern flour milling techniques are directed towards effecting the clean separation of the endosperm from the outer husk and germ, wheat flour is preferred to grain for the manufacture of wheat starch. In Canada hard wheat flours are preferred to soft wheat flours because of the better quantity and quality of high-value gluten co-products which are obtained.

To produce starch, flour is fed to a dough mixer where it is combined with water and mixed to form a dough. The dough is then fed into a hopper where it is given a rest period to allow the gluten to hydrate fully and strengthen. Separation of the starch then takes place by washing the mixture with water at a controlled temperature in a machine known as an extractor. The starch slurry is then purified by passing it through sieves and screens to remove extraneous material. At this stage, the starch bearing liquid is centrifuged to separate the starch and water. The starch now contains about 40% moisture and further drying reduces the moisture level to approximately 12%, the usual level at which starch is sold commercially.

CHART 1

THE CORN REFINING PROCESS



SOURCE: Corn Refiners Association, Washington.

Concurrent with this process, the gluten which was separated from the starch in the extractor, is dried at a low temperature to maintain the desired vitality. It is then ground, sieved, and packed for shipment. Devitalized gluten is also produced by drying at a higher temperature and/or longer period. A flow-sheet of this process is shown in Chart 2.

It is notable that no other by-products are obtained through this process because the raw material (flour) is a semi-processed product. The by-products of flour milling, brans, shorts, and middlings which are sold as animal feed, were separated in the initial milling process.

Starch from Potatoes

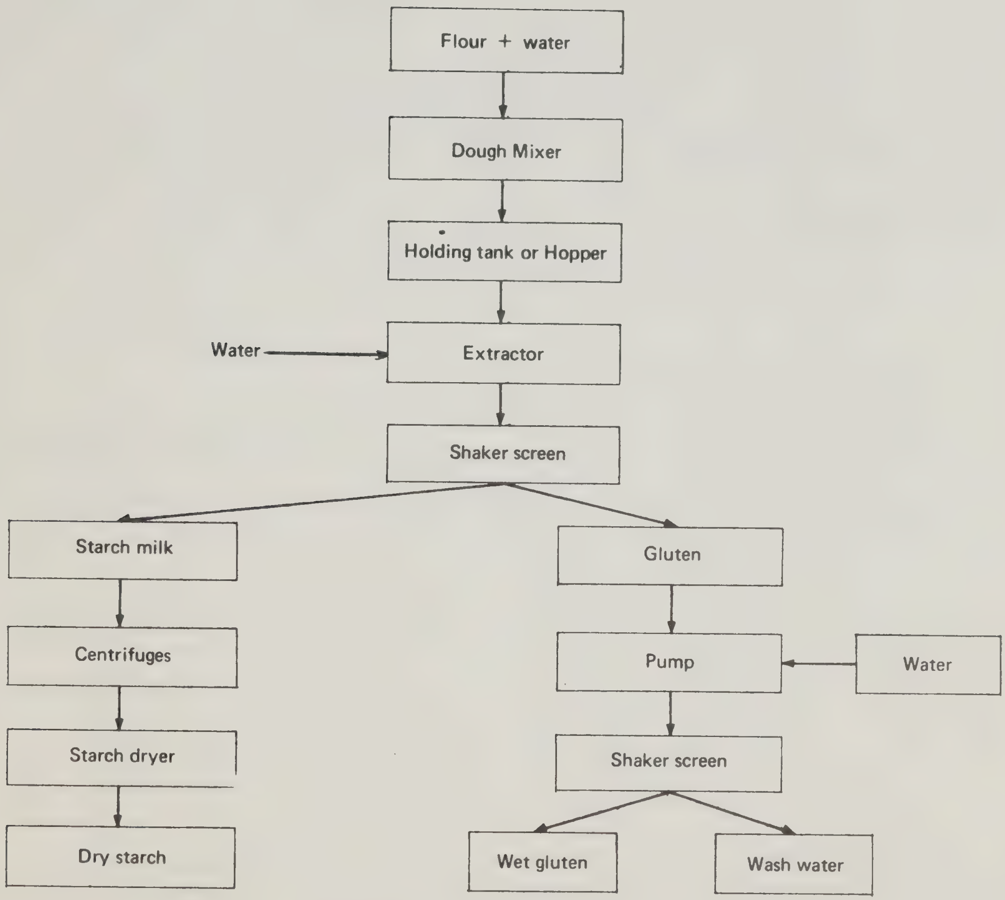
Starch from potatoes, the smallest segment of the industry, currently accounts for less than 2% of total starch production.

In Canada the raw material for the manufacture of potato starch is the common garden variety of potatoes. Normally about 15% of the potato crop consists of sub-standard potatoes unsuitable for the table market because of their size, shape or damage. These potatoes, known as culls, are the primary raw material for the manufacture of potato starch in Canada. However, the available supply of culls is so limited that continuous production cannot be maintained. In times of surplus, table grade potatoes may be used, but it is usually uneconomical to use these higher grades because the market price of starch is not sufficient to justify purchases of quality potatoes.

The process by which starch is obtained from potatoes is relatively simple vis-à-vis the production of either corn or wheat starch (see Chart 3). As the potatoes move from the storage bins to the rasp or disintegrator, they are washed to remove the dirt, and then reduced to a slurry by the rasp. This slurry is diluted with water to facilitate subsequent screening and sulphur dioxide is added to inhibit the action of oxidative enzymes and thereby aid in producing a white starch. The diluted slurry is then pumped to a battery of screens which allow

CHART 2

PRODUCTION OF WHEAT STARCH AND GLUTEN

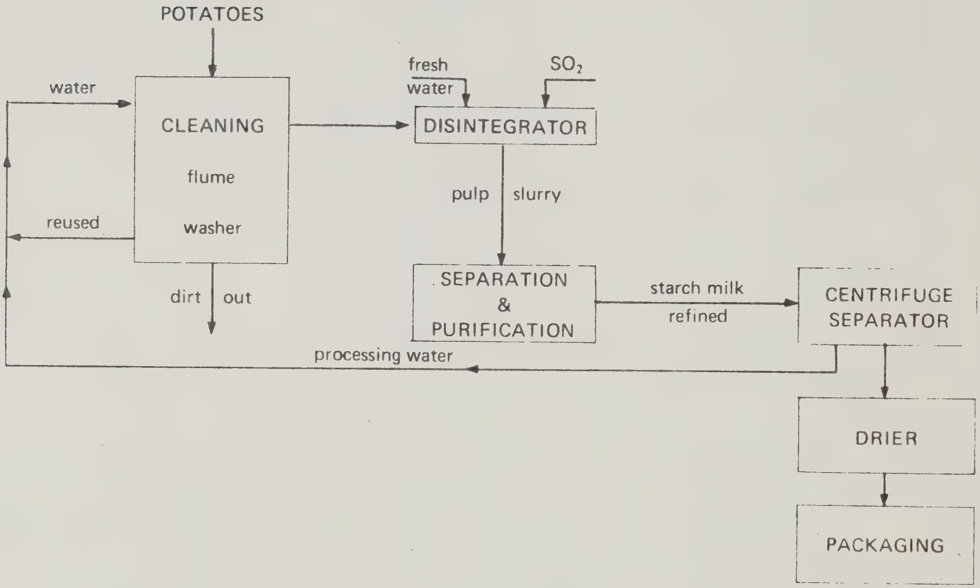


the starch to pass through while retaining most of the non-starch material.

The final separation is achieved by a centrifugal separator, after which starch is dried.

CHART 3

FACTORY PRODUCTION OF POTATO STARCH



The by-product of this process i.e. all of the non-starch material of the potato, is relatively low in value and is used primarily as a fertilizer or in cattle feed mixes.

B. PRODUCTS PRODUCED BY THE CANADIAN STARCH INDUSTRY

The starch which is obtained from any one of the three raw materials may be (a) used in the form in which it is dried, (b) further processed to produce many different types of starch or dextrine or (c) converted to sweeteners (glucose and dextrose) and other products.

It is beyond the scope of this study to attempt to describe each of the several hundred product grades produced by the industry. Descriptions of the characteristics and chief applications of the major types of starch products are given below. Subsequent sections, which provide similar information about starch-based sweeteners, also discuss the manufacturing of these products in greater detail.

Unmodified Starch

Unmodified starch is the starch which is obtained directly from the raw material in each of the processes described above. It is also known as regular, thick boiling, prime, or raw starch. All starch manufacturers produce prime starch. As noted, it is usually dried and sold in a granular form, known as pearl starch, or as a powder. Large quantities of regular starch are used as sizes for paper and textiles, and as an adhesive by corrugated board and carton manufacturers. Products in this group are also used by breweries. manufacturers of laundry starch, food products (e.g. puddings, canned foods, confections, baking powder), adhesives, pharmaceutical goods, and in printing operations.

Modified Starches

Starch may be treated with many other substances to yield products of widely different characteristics. For this reason, starch has come to be regarded as a convenient and economical "building block" for an increasing variety of compounds in which a significant change in basic properties of the starch is effected by substituting some of the chemical groups of the starch molecule with groups from other compounds.

Among the more common chemical reactions used in these conversions are hydrolysis, oxidation, cross-linking and substitution. The major types of modified starches produced by these and other chemicals are described below.

Thin Boiling Starch

Thin boiling starches are usually made by acidifying starch slurried in water and holding the slurry under controlled temperature conditions until the desired degree of conversion or modification has taken place. Conversion may be described as the shortening of starch molecules. When conversion occurs, cooked solutions of starch and water are less viscous. Once the desired degree of starch conversion has been reached the acid is neutralized and the starch is dried. Modified starches are produced in a fairly broad range of viscosities, which may be adapted to meet special requirements in different applications. In Canada, the greatest range of thin boiling starches are produced by corn and wheat starch manufacturers.

A major use of thin boiling starches is in the manufacture of gypsum wallboard. It is also used as a component of gumdrop candies and for textile sizing.

Oxidized Starch

Oxidized starches, another type of modified starch, are prepared in a manner similar to thin boiling starches but sodium hypochlorite is used in place of acid as the conversion agent. Modification with this chemical increases the stability of the starch paste, which means that it does not set or harden (gel) as readily. It also produces a clearer or less opaque paste.

The fine paper industry is the largest user of oxidized starch. In this industry it is used for sizing and the manufacture of clay-coated papers.

Pre-Cooked Starches

A pre-cooked starch is one which has been cooked and then dried on hot rolls. When the starch again comes in contact with water, it will swell and become viscous without further cooking. These products known as pre-cooked, cold water swelling, or pregelatinized starches, have many uses. When added to wood pulp at the beater, it helps to produce stronger paper. Some grades are used to form sand cores in foundry operations; others are used in "instant" food products such as puddings; and still others are employed to control the viscosity of the 'mud' in oil well drilling operations.

Pre-cooked starches in Canada are presently produced in the corn and wheat starch segments of the industry.

Cross-linked Starches

Cross-linked starches are chemically treated to reinforce the granule which, in turn, inhibits swelling and raises the gelatinisation temperature range. The objectives achieved by the reaction are:

(a) to change the "long" or stringy texture of certain starch pastes, (particularly waxy types) to a pleasant short textured mouth feel;

(b) to stabilize the paste against heat and mechanical breakdown and low pH conditions;

(c) to give a starch of higher viscosity.

Reagents used in cross-linking are borax (weak, temporary), epichlorohydrin, phosphorus oxychloride, certain phosphates, aldehydes and dialdehydes and a variety of other less common reagents.

Cross-linked starches are used in pie fillings, (including fresh, frozen and canned types), canned soups, gravies, and sauces. Other food uses include baby foods and salad dressings. They are particularly useful where heat sterilization is required.

Non-food uses are widespread and include waterproofing of cardboard boxes, paper and textile sizing, and in certain printing pastes. Additional uses are reported in adhesives, oil-well drilling muds, paints, and certain dusting applications.

Several types of cross-linked starches are made by various starch manufacturers.

Other Modified Starches

(a) Starch Derivatives

With the exception of oxidized starches, starch ethers are probably the most commercially important starch derivative. There are several types, but the principal ones are hydroxyalkyl starch ethers and cationic starch derivatives.

Cationic Starches are a very widely used group of starch derivatives whose importance derives from their affinity for negatively charged substrates such as cellulose, some synthetic fibres, certain minerals and some biologically active polyanions. A number of different types exist depending upon the substituent used and, as always, the degree of substitution.

In the paper industry, cationic starches are used as wet end additives, and as emulsifying agents and retention aids for pollution control. They have found less acceptance in the textile industry because of high costs and problems of soil redeposition in laundering. However, advantages include resistance to loom abrasion, a reduction of static electricity, and reduced amount of starch needed. They also find use as flocculating agents in mining operations and purification of waste waters.

Hydroxyalkyl Starches are widely used commercially, the most common substituents being hydroxyethyl and hydroxypropyl. Substitution by these groups results in a reduced gelatinization temperature range, an increased swelling and dispersion rate, improved paste clarity and cohesiveness, and decreased tendency to retrogradation. Because of their

desirable film forming properties, hydroxyalkyl starches are used in the paper industry for surface sizing and to improve paper strength and stiffness. Low degree of substitution (D.S.) derivatives are very useful adhesives in paper coating colours.

In the textile industry these starches are used for warp sizing, finishing and printing, and the glazing of threads. They are also used as laundry starches and in foodstuffs for pie fillings, salad dressings and thickeners.

Highly substituted hydroxyethyl and hydroxypropyl starches are water and alcohol soluble and thermoplastic. There is no retrogradation and they have excellent freeze-thaw stability, and resistance to microbiological spoilage. These high D.S. derivatives are less widely used than the low D.S. but are used in the textile industry for warp sizing, as adhesives, and in certain pharmaceutical applications.

(b) Starch Esters

The major organic ester of starch is the acetate. Since this substitution has the effect of disrupting the intermolecular forces within the granule, the usual general properties of decreased gelatinization temperature, improved low temperature stability and improved paste clarity result. Films have greater clarity, higher gloss, less brittleness and are more easily dissolved in water.

Starch acetates are acceptable for use in foods where they give good clarity and stability and high viscosity. Acetylation is sometimes used in conjunction with cross-linking to produce starches of improved freeze-thaw stability.

Waxy Maize

The foregoing categories represent the more important types of special starches. At this point it is appropriate to comment upon starch produced from waxy maize, a special type of corn, the starch of which differs in many respects

from regular corn starch. The most distinctive difference pertains to the characteristics of the waxy starch paste, which is clearer, more fluid, and more adhesive. These characteristics are particularly advantageous in the canning industry where these properties result in products of better quality and/or more attractive appearance.

Waxy starches are also modified to change their specifications in the same manner as regular starch. The major use of modified waxy maize is in processed foods. It is also used as a stabilizer in pie fillings and salad dressings. In the non-food area it is employed as an adhesive on gummed paper tape.

Dextrines

Dextrine is the product obtained by roasting acidified dry starch. By controlling the acidity and roasting temperature, a wide range of products can be produced with varying levels of solubility and viscosity.

There are two principal types of dextrines: white and yellow. Yellow dextrines are highly soluble and relatively thin boiling which makes them useful as adhesive ingredients and in ore separation. The less soluble and thicker boiling white dextrines are used in textile finishing, paints and insecticides.

Dextrines are produced in Canada by corn and wheat starch manufacturers, and by firms outside the industry which buy potato starch and process it into dextrine.

Starch Derived Products

In addition to the forenoted products which are essential variations of basic starch, starch may be also converted into products whose characteristics are distinctively different. Of these the most important are the starch-based sweeteners described below.

Glucose Syrup

Glucose syrup is a clear, colourless, non-crystallizing,

viscous liquid. It is known in Canada as glucose and in the U.S. as corn syrup or corn syrup unmixed (C.S.U.). It consists of mixtures of dextrose, maltose, and higher saccharides and is produced in many grades with varying combinations of these carbohydrates. The standard product most used in industry is 43° Baume (approximately 80% solids) 42% Dextrose Equivalent (D.E.). In Canada glucose is produced only from corn starch in grades varying from 40 to 45° Baume, 74 to 85% solids and 25 to 70% D.E.

Although glucose is only made from corn in Canada, this product can be produced from any type of starch and the crop of preference in a country is normally the ~~same~~ as that for starch production. This is not to say that all starches are equally easy to use. Generally speaking, potato starch is easier to process than corn starch, and corn starch is easier than wheat. With processes at present in use, the starch must be of high purity in order to avoid the development of undesirable flavours and colours. As technical improvements occur, particularly those based on enzyme technology, the raw material requirements may change; for instance, a particular starch source might be preferred or a less pure source of starch, or even a flour, might be used.

There are basically two commercial processes, the acid process and the acid-enzyme process. Acid hydrolysis proceeds by random splitting of the starch molecule and is unable to produce an acceptable product much higher than 65% D.E. and 42% glucose content. The manufacturer using acid hydrolysis has relatively little control over the proportions of glucose, maltose and higher oligosaccharides, whereas the enzyme process permits a range of D.E. products and considerable control over the percentage of glucose, maltose, and higher oligosaccharides. Thus, enzyme produced syrups may be higher in desirable fermentable sugars, may be sweeter, and generally possess a range of physical and textural properties that command a wider market. High dextrose and high maltose syrups and the low D.E. syrups

of reduced sweetness and fermentability are all important products whose development was dependent on the use of enzyme processes.

In the acid process a purified starch slurry is mixed with a small amount of dilute acid. This mixture is pumped to a batch reaction vessel or through a continuous tubular type heat exchanger where, under pressure, the temperature and time of the reaction are controlled. As the reaction progresses the gelatinized starch is converted first to polysaccharides of lower molecular weight than the starch and subsequently to sugars, mostly maltose and glucose. The hydrolysis reaction is halted when only partially complete, the exact level depending on the D.E. of the glucose syrup being made.

When the conversion has reached the desired point the reaction is terminated by reducing pressure to zero and neutralizing the converted material to a pH level of 4 to 5 with sodium carbonate. The neutralization aids in flocculating residual fats and protein in the starch which are removed by filters or centrifuges.

In the acid-enzyme process the acid hydrolysis is followed by conversion with a purified enzyme resulting in a glucose syrup of high maltose or glucose content. The glucose-maltose ratio can be varied within certain limits by the type of enzyme used and by the extent of the preliminary acid conversion.

The resulting syrup from either process is passed through vegetable carbon filters for further clarification and decolourization, producing a clear colourless liquor which is evaporated in vacuum evaporators to the desired concentration. After cooling the glucose syrup is ready to load into tank cars, tank trucks or drums.

Although the sweetness of glucose syrup makes it a competitor of sucrose, it possesses a number of functional properties that make it quite distinct. From a technical

point of view it is a more versatile product which can be "tailor-made" to control sweetness, body, texture, gloss, clarity, and crystallization in the production of food products. One of the major uses is to control crystallization in confections, ice cream, other frozen desserts, jams, jellies and preserves. The proper blend of glucose and sugar lengthens the shelf-life of chewing gum and aids production. Other uses include control of flavour and smoothness in jams, and jellies, colour and flavour of ketchup and pickles, the enhancement of crust browning in fresh and frozen bakery items, and as an adjunct in the production of beer and ale.

Glucose Solids

Glucose solids is an amorphorous product obtained by dehydrating liquid glucose. It is produced by spray drying or by drying glucose in a vacuum evaporator, after which it is cooled on a chilled belt or roll. The resultant dry product has the characteristics of glucose when mixed again with water. Glucose solids is used as a base for coffee whiteners, as carriers in dried soups and spices, and in peanut butter to enhance flavour and aid spreadability. It is also used as an ingredient in instant breakfasts, baby formulas, ice cream, confectionery and as a humectant in adhesives.

Dextrose

Dextrose is a fine, white, crystallized, refined sugar with an appearance close to typical household sugar (sucrose). It is obtained by hydrolyzing the starch to the highest possible D.E. After conversion, refining and evaporation, the dextrose is crystallized from the mother liquor under carefully controlled rates of cooling. The process generally used is acid-enzyme conversion but in Japan all dextrose is produced by enzyme-enzyme methods. The conditions of the process are so adjusted to give a maximum glucose content in the hydrolyzate. After purification and concentration, as in the manufacture of glucose syrup, the highly refined dextrose liquor is seeded with

dextrose crystals from a previous batch. Crystallization is then carried out in large crystallizers equipped with spiral agitators.

After approximately 100 hours in the crystallizers, the crystalline dextrose is separated from the mother liquor in centrifuges, washed, dried, screened and packed.

Dextrose produced in this manner is the monohydrate and contains approximately 8.5% moisture. The production of anhydrous dextrose involves still further processing.

Dextrose is a product of many uses. It is frequently used to maintain the solids level in food products without creating excessive sweetness or masking delicate flavours. In bakery products and bakery mixes, dextrose helps browning and provides fermentable sugar. Since the crystallization rate of dextrose is distinct from other sugars it is used for crystallization control and moisture retention in confectionery and food products. Bottlers use dextrose in carbonated beverages to raise the sugar content for body and gas retention without masking flavour or making the drink excessively sweet. Canners and pickle manufacturers use the higher osmotic pressure of dextrose to penetrate the fruit or pickle to help retain natural form, colour and flavour. Dextrose is also used as a spice carrier and is added to peanut butter, sweetened condensed milk, frozen desserts and ice-cream, wines, cordials, and liqueurs. Dextrose is also a base material for the production of sorbitol.

Although the applications for dextrose are many, the market is relatively small and only one cornstarch company is presently producing the product in Canada.

By-Products of Starch Production

Reference has been made previously to the by-products which are obtained from the various starch processes.

Table 2 - USES OF STARCH AND STARCH PRODUCTS

	Unmodified	Enzyme Converted	Thin Boiling	Oxidized	Pre-cooked	Dextrine
ADHESIVES:						
Bill Posting	x				x	x
Corrugated Paper	x		x	x		
Envelopes						x
Laminated Fibre		x	x	x		x
Paper Bags	x	x	x	x		x
Paper Boxes (lining)			x		x	x
Paper Tubes & Cones	x		x		x	x
Postage Stamps						x
Gummed Tape						x
BATTERIES:						
Dry Cell	x					
BOILER COMPOUNDS:	x					
BRIQUETTES:						
Coal	x				x	
Crayon (Chalk)			x	x		x
Metals	x	x				x
CERAMICS:	x	x	x	x	x	x
CHEMICALS:						
Organic Acids	x					
Organic Solvents	x					
CIGAREETE SEALING:	x	x				
CORD POLISHING:	x	x				x
CORK PRODUCTS:	x		x			x
COSMETICS:						
Hair Waves	x					
Shaving Cream	x					
Powders	x					
Tooth Paste	x					
DETERGENTS:	x				x	
DYES:						x
EXPLOSIVES:						
Dynamite	x					
Fireworks	x					
Nitrated Starch	x					
Various					x	
FOODS:						
Bakery:						
Cakes	x					
Cookies	x					
Dusting	x				x	
Flours	x					
Ice Cream Cones	x					
Macaroni	x					
Pie Filling	x			x		
Prepared Mixes	x				x	
Wafers	x					
Brewing:	x	x			x	
Canned Foods:						
Canned Vegetables	x					
Soup	x			x		
Thickeners	x					
Confectionery:						
Caramels	x					
Chewing Gum	x				x	
Dragee	x					x
Dusting	x				x	
Gum Work	x		x	x		
Molding	x					
Pan Coatings					x	x
Dairy Foods:						
Condensed Milk						x
Stabilizers	x					x

Table 2 (con't)

	Unmodified	Enzyme Converted	Thin Boiling	Oxidized	Pre-cooked	Dextrinc
Desserts:						
Pudding Powders	x			x	x	
Meat Products:						
Sausage & Load as Binders	x					
Miscellaneous:						
Animal Foods	x				x	x
Baking Powder	x					
Condiments	x				x	
Rice Polishes						x
Salad Dressing	x			x		
Sugar Powdered	x			x		
Yeast	x					
Films	x					
FOUNDRIES:						
Sand Binder					x	x
INSECTICIDES:	x					x
INSULATIONS:						
Glass Wool	x					
Rock Wool	x					x
LAUNDRY:						
Bluing	x					x
Commercial	x		x	x		
Home	x	x	x	x	x	
LEATHER:						
Adhesives						x
Shore Counter Paste	x		x			x
Shoe Polish	x					x
LINOLEUM:						x
LUMBER TREATMENT:	x					
MINING:						
Ore Flotation	x		x	x		
Oil Well Drilling					x	
Process Control	x				x	x
Settling	x				x	
PAINTS:						
Cleaning Compounds	x				x	
Cold Water Paste					x	x
Poster	x					x
Sizing	x					
PAPER:						
Beater Size	x				x	
Calendar Size	x	x	x	x		x
Coatings	x	x	x	x		x
Tub Size	x	x	x	x		x
Wall Paper		x	x	x		x
PHARMACEUTICALS:						
Starch Tablets	x			x		
Surgical Dressings					x	
PLASTICS:						
Miscellaneous	x			x	x	x
Extender	x					
Molded	x					x
Coatings	x					x
PLYWOOD & VENEERS:	x			x		
PRINTING:	x					x
PROTECTIVE COLLOIDS:						
Emulsions	x		x	x	x	x
RAYON MANUFACTURE:	x					
RUBBER:						
Battery Plates	x					
Dusting	x					
SILVER COMPOUNDS:	x					x
SOAP & DETERGENTS:	x				x	x
TEXTILE:						
Printing	x			x		x
Finishing	x	x	x	x	x	x
Rug Sizing		x				x
Screen Printing						x
Stiffening	x		x			x
Warp Sizing	x	x	x	x		x
WATER TREATMENT:					x	
WINDOW SHADES:	x					x

Table 2 (cont'd)

USES OF GLUCOSE, DEXTROSE & CARAMEL COLOUR

	Glucose	Glucose Solids	Dextrose	Caramel Colour
Confectionery				
Hard Candy	x	x		
Gum Drops	x	x	x	
Chocolate		x	x	
Marshmallow	x		x	
Chewing Gum	x			
Beverages				
Lemonade, frozen concentrate	x	x	x	
Orange Juice	x	x	x	
Carbonated			x	x
Powdered Drink Mixes				
Coffee Powder		x		
Chocolate Powders		x		
Bakery Products				
Bread			x	x
Rolls			x	x
Buns	x		x	
Cakes	x	x	x	
Toppings & Frostings				
Pie Fillings	x	x	x	
Cookies	x	x	x	
Pancake Mixes		x	x	x
Salad Dressings	x	x	x	
Dairy Products				
Cheese Spreads	x	x	x	
Cottage Cheese		x	x	
Ice Cream	x	x	x	
Milk Condensed			x	
Yogurt	x			
Frozen Desserts	x	x	x	
Coffee Whitener	x	x		
Cereals	x	x	x	
Eggs				
Frozen Yolks		x		
Dried Whites		x		
Fish				
Frozen Fillets	x	x		
Frozen Shell Fish	x	x		
Pickles	x		x	
Jams & Jellys	x	x	x	
Baby Foods	x		x	
Catsup	x	x	x	
Canned Fruits & Vegetables	x	x	x	
Meats				
Hams, Bacon	x	x	x	
Bologna		x		
Sausage		x		
Frankfurters		x		
Frozen Meat Pies	x		x	
Peanut Butter		x	x	
Sauces	x	x	x	x
Condensed Soups	x	x		
Dried Soups		x	x	x
Spices		x	x	
Cordials & Liquers	x		x	
Beer, Ale	x		x	
Wine	x		x	
Tablets, Pills		x	x	
Adhesives	x			

Descriptions of the chief characteristics of these by-products, their uses, and an indication of the revenue obtained from them are given below.

Steepwater

Steepwater is the concentrated solubles from the corn refining process. These concentrated solubles contain a minimum of 40% protein and are often sold in liquid form as a high protein supplement for beef cattle feeding. Because of the great variety of the soluble proteins and minerals contained in steepwater, it can also be used by antibiotic manufacturers as the medium for the growth of penicillin, aureomycin and other antibiotics. As volume of sales is relatively small and steepwater is also included in gluten feed or meal, a separate calculation of market value has not been made.

Corn Oil

Corn oil which is extracted from the dried corn germ is the most valuable by-product of wet corn milling. After refining, the corn oil is clear, light golden in colour and possesses a bland, pleasing taste. Because corn oil has a high percentage of unsaturated fatty acids, a high smoke point, and a low solidifying point, it is a premium quality cooking and salad oil. The yield of crude corn oil is about 1.7 pounds per bushel, having a market value of approximately 27¢/bushel.

By-Product Feeds

By-product feeds, which include corn gluten feed, corn gluten meal and corn oil meal contain the essential amino-acid content and balance of protein of the corn kernel. They are a good source of some amino acids (e.g. methionine) but relatively short of others (e.g. lysine). In general

gluten feed and meal are used in formulated feeds in combination with other ingredients to provide a balance of protein and energy requirements which result in optimum growth factors. The use of corn gluten as human food has potential for development. Gluten feed and meal produces a revenue of approximately 50¢ per bushel of corn.

Corn Gluten Meal is the dried gluten or protein portion of the corn. It may or may not contain a portion of the corn solubles. The guaranteed protein (commercial basis) is normally 60 per cent, fat 1.0 per cent minimum, and fiber 2.5 per cent maximum.

Among protein concentrates gluten meal is one of the few sources of beta-carotene (Vitamin A) and xanthophyll. This high protein meal has been found to stimulate growth and feed conversion of poultry fed balanced rations. In broiler feeds, the supplementary xanthophyll produces a desirable pigmentation in a dressed broiler. This product also has a long history as a protein ingredient in dairy rations.

Corn Gluten Feed is that part of the corn which remains after the extraction of the larger portion of the starch, gluten and germ. It may or may not contain a portion of the corn solubles (steepwater), or corn oil meal. Guaranteed protein on a commercial basis is normally 21 per cent, fat 1.0 per cent minimum, and 10 per cent maximum fiber content. It is sold either in coarsely ground form, or pelletized and sold in the whole pellet or kracklet form.

Gluten feed is used in formulas for chicken and turkey growing, and for poultry laying and breeder mashes. It has also proven satisfactory in high protein supplements for hogs and in pig starters, and is desirable in dairy and beef cattle feeds because of its total digestible nutrients and digestible protein content.

Corn Oil Meal consists of the corn germ from which most of the oil has been removed by hydraulic expeller or solvent extraction. Containing a minimum protein

content of 20% commercial base, corn oil meal is also used in animal feeding and as the carrier in special antibiotic mixes used in animal feeding.

Wheat Gluten

Starch co-product, rather than by-product, would probably be a more accurate description of the non-starch product obtained from the wheat starch production process.

Wheat gluten is the protein fraction of flour which may be produced in either vital or devitalized form. The former is prepared by a low temperature drying process which produces characteristics useful to the bread making industry. Vital gluten is added to low protein flour to improve its baking properties. Used by bakeries, it produces a loaf of greater volume and better crumb texture, which is less subject to staling. Vital gluten is also used in dried breakfast cereals, pasta and pet foods.

Devitalized gluten was used at one time for the manufacture of mono-sodium glutamate (M.S.G.) which is now produced at lower cost from other raw materials. At the present time it is used to manufacture hydrolyzed vegetable protein products.

Secondary Wheat Starch is a lower grade of starch containing a higher percentage of protein. This product is used in the manufacture of products where the higher protein content is not detrimental. It is used in the production of fibre board, wallboard, foundry cores, charcoal briquettes and pet foods.

Potato By-Product

As noted in the description of the production process, the by-product of potato starch is usually used as an animal feed or fertilizer. It has little commercial value relative to the by-products of other raw materials used in starch production.

Competitive Products

At one time the printing of textile fabrics, particularly cotton fabrics, used starch as the dye carrier in the printing pastes. This is no longer true as most textile printing is now done with pigments instead of dyestuffs, with acrylic resins generally being used to bind the pigments to the fabrics. The resin provides a permanent bond for the pigments and starch does not serve this purpose.

In the finishing of textile fabrics to impart the proper "hand" to the fabrics, dextrines and starch were used to a great extent. This is no longer true although some of these products are still used. Generally they have been replaced by resins such as Urea-Formaldehyde and Melamine types due to the change in demand in the type of textile fabrics required. These resin finishes give permanent wash-proof, crease-resistant finishes which cannot be duplicated by starch products.

In textile warp sizing, starch is still the foremost agent, due primarily to its low cost. However, with the continued growth of man-made fibres, Polyvinyl Alcohol (PVA) and Carboxymethyl Cellulose (CMC) are gaining in use. PVA costs about four times as much as starch, but the film strength of PVA used for sizing runs at about 10,000 to 16,000 psi vs. about 800 psi for starch. By using this much stronger film, considerably less add-on can be used (than when using starch). This has made PVA sizing a commercially feasible operation. The higher cost of using PVA is often justified by increased performance and easier desizing of the fabrics. In the use of CMC about one third as much CMC as starch is used for warp sizing, which means that the overall cost of sizing is about 50% higher with CMC than with comparable starch size performance. However CMC is a watersoluble material and the fabrics sized with CMC can be readily desized in hot water alone without use of enzymes or costly boil-off treatments. The use of

CMC reduces the need for water pollution control.

At one time dextrines were used as backing in the manufacture of carpets. However, this product has now been replaced by rubber latex which is more resistant to slipping.

In the adhesive industry dextrines have been replaced to some extent by resins. However, it would appear that dextrines will always maintain a position in the production of low-cost liquid adhesives.

In the sugar refining industry up to 5% starch is used as an anti-caking agent in icing sugar. Some inroads into the use of low-moisture starch have been made by a mineral additive, sodium alumina silicate. This product is slightly cheaper than low-moisture starch and only one-half as much is required as of starch so that the economics are interesting to the icing sugar manufacturers. This also enables the sugar manufacturers to use and sell more sugar. The use of sodium alumina silicate was approved for use in icing sugar in Canada by the Department of National Health and Welfare.

C. CANADIAN MARKET FOR STARCH & STARCH-DERIVED PRODUCTS

Analysis of the role of the starch industry in the Canadian economy is hampered by a lack of factual data. This lack is the result of Statistics Canada regulations prohibiting the publication of data which could reveal confidential information about an individual company. In this instance, the small number of companies producing starch and the still fewer number producing certain product lines, prevent the publication of production data. A complicating factor is that trade data relating to starch and non-starch products are often combined, thus effectively hiding the actual trade in these goods. Despite these difficulties, the Committee considered it essential to define the parameters of the starch industry in Canada. Accordingly, the following industry profile has been developed from available published data and estimates prepared by Committee members.

Consumption

Total domestic consumption of starch, glucose, dextrose, dextrines, and other products produced from starch is estimated at 479 million pounds in 1969, compared to an average of 268 million during the three years 1957/9 (Table 3). During this period, starch consumption doubled from 108 to 237 million pounds and increased as a percentage of total consumption from 40% to 50%. Glucose ranks second to starch in terms of volume and increase in consumption. The estimated 148 million pounds used in 1969 is an increase of 82% over the base period. The share of total consumption held by glucose also rose from 28% to 31%. Although usage increased from 14 to 20 million pounds, dextrine declined in importance relative to total consumption and now represents 4.2% of the total vs. 5.2% in the base period. Similarly, other products, including consumer lines and the less important industrial products show a constant volume but a decline from 20% to 11% of total consumption.

TABLE 3

ESTIMATED CANADIAN MARKET FOR STARCH & STARCH-DERIVED PRODUCTS

(Million Pounds)

	Average 1957/9	1966	1967	1968	1969
Starch	107.8	199.3	205.0	212.3	237.4
Glucose	79.6	126.3	130.0	148.4	148.6
Dextrose	11.9	13.2	14.5	17.5	18.0
Dextrine	14.0	18.0	18.0	19.0	20.0
Other Products (1)	55.0	55.0	55.0	55.0	55.0
	268.3	411.8	422.5	452.2	479.0

(1) Includes consumer and industrial products.

The paper industry has traditionally been the most important outlet for starch. In 1969, this industry used 113 million pounds of starch, which was equal to nearly one-half of the total starch used in Canada. In this industry, more than 90% of the starch is used in the manufacture of fine paper. Second in importance is the corrugating industry, which took 28 million pounds in 1969. For glucose, the most important market is the confectionery industry which traditionally accounts for 45% of total domestic consumption. Dextrines are used primarily in the adhesives industry, but important quantities are also used in numerous other applications where adhesive properties are important. Details of usage by these and other industries are provided in Tables 4 to 7.

In respect to regional usage patterns, it is evident from the number of industries listed in the aforementioned tables that consumption of these products tends to follow the general pattern of industrial development in Canada. For this reason, Ontario and Quebec are judged to account for about 75% of the total volume. Important quantities of starch are used by paper and corrugating manufacturers in other regions.

Sources of Supply

Canadian requirements of starches and starch-based products are met from domestic production and imports. Exports of these products are negligible, and the Canadian industry is therefore oriented to meeting domestic requirements. Although production substantially exceeds imports and would normally be discussed first, it is preceded by the trade section because data therein is then used to estimate production.

Canadian Trade

A discussion of Canadian trade in starch and starch-derived products is really limited to imports. Exports are considered to be negligible (less than one percent of the

TABLE 4

ESTIMATED CANADIAN CONSUMPTION OF STARCH

(Million Pounds)

	Average 1957-9	1966	1967	1968	1969
Non Food:					
Paper	44.2	90.8	97.3	97.6	113.8
Corrugating	14.1	20.0(e)	21.5(e)	23.2	28.0
Textile	10.8	14.9	15.5	15.5	16.8
Gypsum (1)	5.0	5.6	7.4	7.3	8.8
Chemical-Other	1.1	1.2	0.8	1.2	1.2
	75.2	132.5	142.5	144.8	168.6
Food & Pharmaceutical:					
Bakeries	1.0	2.2	2.2	1.7	1.7(e)
Biscuit	.8	1.5	1.6	1.6	1.8
Confectionery	3.9	7.0	5.9	6.8	5.9
Fruit & Vegetable Preparation	4.0	8.3	8.3	9.4	9.0
Misc. Food	8.8	17.2	13.8	15.6	16.8
Sugar	2.4	2.5	2.4	2.4	2.6
Pharmaceuticals	0.7	1.1	0.8	0.9	1.0
	21.6	39.8	35.0	38.4	38.8
Unclassified (e)	11.0	27.0	28.0	29.0	30.0
TOTAL:	107.8	199.3	205.5	212.3	237.4

(e) Estimate

Source: Statistics Canada
& Committee Estimates

TABLE 5

ESTIMATED CANADIAN CONSUMPTION OF GLUCOSE

(Million Pounds)

	Average 1957/59	1966	1967	1968	1969
Non-Food:					
Other Chemicals	0.6	0.6	1.3	1.4	1.2
	0.6	0.6	1.3	1.4	1.2
Food:					
Bakeries	1.5	4.4	3.1	4.4	3.5'
Biscuit	5.7	7.3	9.3	11.0	13.6'
Breakfast Cereals	0.7	0.3	0.3	0.4	0.3
Breweries	-	-	-	3.9	10.5
Carbonated Bvgs.	-	1.5	-	-	-
Confectionery	45.9	60.5	58.9	66.2	59.0
Dairy/Ice Cream	4.8	13.3	14.5	14.0	27.0
Food-Misc.	4.1	12.5	15.5	18.8	13.2
Processed Fruits & Vegetables	6.9	7.1	7.4	8.5	7.9
Pharmaceuticals	1.4	1.8	1.7	1.8	1.4
	71.0	108.7	110.7	129.0	136.4
Unclassified (e)	8.0	17.0	18.0	18.0	11.0
TOTAL:	79.6	126.3	130.0	148.4	148.6

(e) Estimate

Glucose not separated from molasses, honey and other non-sucrose sweetners. Estimate based up 1968 ratio.

Source: Statistics Canada & Committee Estimates

TABLE 6

ESTIMATED CANADIAN CONSUMPTION OF DEXTRINES

(Million Pounds)

	Average 1957/59	1966	1967	1968	1969
Other Chemicals	7.9	8.4	6.3	7.3	8.7
Unclassified	6.1	9.6	11.7	11.7	11.3
	14.0	18.0	18.0	19.0	20.0

Source: Statistics Canada & Committee Estimates

TABLE 7

ESTIMATED CANADIAN CONSUMPTION OF DEXTROSE

(Million Pounds)

	Average 1957/59	1966	1967	1968	1969
Confectionery	2.4	2.6	3.7	5.3	6.4
Pharmaceutical	0.5(e)	0.6(e)	0.8	0.7	0.6
Unclassified	9.0	10.0	10.0	11.5	11.0
	11.9	13.2	14.5	17.5	18.0

Source: Statistics Canada & Committee Estimates

Canadian market); figures are not available because Canadian trade statistics do not classify starch exports separately. Generally higher domestic prices of raw materials, foreign tariffs, and high ocean freight rates have been combined to prevent the Canadian starch industry from developing large export markets.

Imports supply a significant portion of the Canadian market for starch and starch-derived products. (Table 8 and Appendix A). In 1969 imports supplied 18.1% of the Canadian starch market compared to an average 12.9% for the period 1957 to 1959 inclusive and 17.4% in the four years 1966-69 inclusive.

The United States, the Netherlands, Thailand, and Brazil provided 92% of Canada's starch imports in 1970. From time to time Poland and South Africa also supply significant quantities. The United States exports consist of corn starch, modified tapioca starch, dextrines, and sweeteners. Tapioca starch exported from the United States represents re-exports since cassava is not grown commercially in that country. Imports from the Netherlands consist mainly of potato starch and dextrines; imports from Thailand and Brazil are limited to tapioca starch.

The United States accounts for over 90 percent of glucose and dextrose imports; these sweeteners are produced by the corn starch industry in that country.

The two principal reasons for the large volume of starch imports are technology and low prices. In respect to the former, a substantial volume of the more advanced types of starch are imported from the U.S. These high-priced starches are usually manufactured for specific uses. In some instances, the technology to produce them may not be available in Canada; in other cases, the demand may be so small that Canadian manufacture cannot be economically justified although the knowledge necessary to produce them is available. Starches in this category are usually highly modified types of corn

TABLE 8

IMPORTS OF STARCHES & STARCH-DERIVED PRODUCTS

(Million Pounds)

	Average 1957/59	1966	1967	1968	1969	1970	1971
Starch							
Corn	12.8	19.4	18.4	20.0	21.8	9.2	5.0
Potato	2.1	9.5	6.9	7.7	13.7	19.8	2.9
Tapioca	1.6	12.7	20.1	15.8	14.6	20.1	9.3
Rice	1.5	0.9	0.7	1.0	1.0	0.8	1.0
Starch n.o.p. (1)	-	3.0	3.0	3.0	3.0	3.0	-
Industrial (2)	-	-	-	-	-	-	29.0
Total Starch	18.0	44.5	49.0	47.5	54.0	53.0	47.1
Dextrines and Dextrine Preparations	4.5	9.5	7.1	5.4	5.0	4.4	4.4
Glucose and Dextrose	12.2	18.0	19.1	20.9	27.9	21.0	23.2
TOTAL	34.7	72.0	75.2	73.8	86.9	78.4	74.7

(1) Estimates of starch imported in chemical section. In 1957/59, included with corn starch.

(2) A new category including all types of starch. Details and estimates of total imports by type are shown in Appendix

Source: Statistics Canada - Imports by Commodities (Cat. No. 65-007)

starch.

Low priced starches are usually unmodified types which undersell Canadian made starch. The most important starches in this category are tapioca starch from South-East Asia and Brazil, and Dutch potato starch. In some years tapioca has captured most of the available starch business in B.C. where it has undersold domestic starch by nearly $2.00/hundred pounds. Dutch potato starch imports vary markedly from year to year as a result of variations in the quantity of potatoes available for starch. There is evidence that the E.E.C. subsidizes exports of starch in years of surplus raw materials and is thus able to compete in Canadian markets (see Appendix B).

Glucose and dextrines are also imported on a price basis. However, glucose is also imported from England. Dextrose is imported because of insufficient capacity in Canada to meet domestic demand. The reasons for this lack of capacity, i.e. the competitive situation of this product with sugar, are discussed later in this report.

Canadian Production

A calculation of domestic production, obtained by deducting imports from domestic consumption, indicates an increase of 68% between 1957/9 and 1969, from 233 to 392 million pounds (Table 9). During this period, starch production increased 104% to 183 million pounds and glucose rose 75% to 139 million pounds. Despite these gains, ratios of production to consumption declined; for starch, from 83.3% to 77.3%; for glucose, from more than 99.6% to 93.3%. The increase in dextrine production raised the share of requirements met by Canadian manufacture to 75% from 68% in the base period.

Prices

By virtue of its domination of the Canadian starch industry, prices of corn starch effectively establish prices of all starches produced in Canada. Corn starch prices in

TABLE 9

ESTIMATED CANADIAN PRODUCTION OF STARCH AND STARCH-DERIVED PRODUCTS

(Million Pounds)

	Average 1957/9	1966	1967	1968	1969
Starch	89.8	154.8	156.0	164.8	183.4
Glucose/Dextrose	79.3	121.5	125.4	145.0	138.7
Dextrine	9.5	8.5	10.9	13.6	15.0
Other	55.0	55.0	55.0	55.0	55.0
	233.6	339.8	347.3	378.4	392.1

turn are based upon the price of unmodified pearl starch with appropriate premiums for other grades. These premiums reflect additional processing costs. Traditionally, prices are established on a regional basis with costs of delivery to the customer's plant included. Price differences between regions are based upon differences in freight rates. In all areas, competitive starch grades are similar to other commodities in that variations in price are most important. For example, it is not uncommon for sales contracts for starch to be won or lost on a price difference of 1/10th of a cent per pound.

Published price lists since 1960 show that the price of pearl starch has fluctuated between \$6.85 and \$8.45/per hundred pounds delivered customers' plant in Southern Ontario. Assuming a typical freight charge from a starch manufacturer to a southern Ontario plant to be 50¢, the f.o.b. factory price for pearl starch is calculated to have ranged between \$6.35 and \$7.95. The price at the end of 1971 was \$7.20. From this base, prices range upwards to \$20.00, and even in excess of \$30.00 for some of the more advanced types of starch. Typical regional premiums over the Ontario prices for all grades of starch are \$1.40 in B.C., and 50¢ in the Maritimes.

Glucose (corn syrup) shows a range and regional structure similar to starch. During the last ten years, factory prices have fluctuated between \$6.50 and \$8.30/hundred pounds. In November 1971, the f.o.b. factory price was approximately \$6.50. The regional structure of dextrines and other products is similar to starch, but price movements have not been as great, probably because the special applications of many of these products tend to isolate them from the intense competitive pricing which characterizes the basic starch market.

An important factor in the pricing of starch in Canada is the close proximity of the Canadian market to U.S. suppliers. This proximity ensures that Canadian prices cannot

be established without regard to prices prevailing below the border. In effect, domestic prices usually do not vary significantly from the price of comparable U.S. grades produced in the U.S. and delivered in Canada, including freight, duty and exchange. The following Table shows the price differentials for starch and glucose which have existed between the two countries. The difference in prices can usually be traced to higher raw material and unit labour costs which occur because comparable economies of scale are not attainable in Canada. It will be noted that the differentials which prevailed between 1961 and 1967 were much smaller than in 1971. This situation has arisen because surplus capacity in the U.S. has led to the

TABLE 10

GLUCOSE AND STARCH
PRICE DIFFERENTIALS
CANADA AND U.S.A.
(per hundred pounds)

	Glucose	Starch
Average 1961/7	$ 1.51	$ 1.32
1971	2.82	2.26

outbreak of a price war, one of several since 1968. These price wars, which sharply reduce prices and profit margins of American companies, have on occasion spilled into Canada. Although Canadian companies have endeavoured to maintain prices and profits at normal levels, these low-priced imports have forced them to reduce prices below normal levels or risk the loss of substantial sales volume.

D. RAW MATERIAL USAGE

Although recognizing that information on the volume usage of each raw material would be useful, the Committee decided not to develop estimates on the grounds that it was necessary to respect corporate confidentiality. As an alternate, total Canadian usage of starch products was translated into equivalent raw materials. The results are shown in Table 11.

TABLE 11

RAW MATERIAL EQUIVALENTS OF STARCH AND STARCH-DERIVED PRODUCTS - 1969

(million of units)

	Potatoes	Corn	Wheat
Production	34.6 cwt.	9.7 bu.	14.4 bu.
Imports	8.6	2.4	3.5
	43.2 cwt.	12.1 bu.	17.9 bu.

This table shows that starch products used in Canada in 1969 were equivalent to (a) 43 million cwt. of potatoes, or (b) 12 million bushels of corn, or (c) 18 million bushels of wheat. Included in this total are imports equivalent to 8.6 million cwt. of potatoes, or 2.4 and 3.5 million bushels of corn and wheat respectively. These results reflect a high level of glucose imports during 1969 and for this reason they may overstate the importance of foreign goods. In both 1968 and 1970, glucose imports were some seven million pounds less than 1969; equivalent to nearly 200,000 bushels of corn, 250,000 bushels of wheat, or 600,000 cwt. of potatoes. In normal years, these quantities would accrue to domestic production.

It is evident from the foregoing discussion that imports are an important consideration to the Canadian starch industry. The following section discusses the international environment in which the Canadian starch economy operates, with particular reference to situations which have a direct impact on the Canadian industry.

SECTION IV: INTERNATIONAL SITUATION

INTERNATIONAL SITUATION

WORLD PRODUCTION

Reliable statistics on world production and trade in starch, starch-derived products and by-products are not available. An attempt to obtain data on a country basis has proven difficult, due either to the absence of the statistics or because of legislation prohibiting their release.

Annual world starch production has been estimated at 22,900 million pounds which means Canadian starch production represents less than 2% of world production. The United States is the largest starch producing country of the world followed by Japan, the Netherlands and the United Kingdom (Table 12).

On a per capita basis, production of starch and starch-derived products in most countries ranges from 5 to 35 pounds per year with industrialized countries generally reporting higher output. Estimated levels of per capita production in the seven countries listed in Table 12 are calculated at:

Netherlands	103.6 pounds
United States	39.6
Japan	26.8
Australia	23.5
Canada	17.5
United Kingdom	17.4
Thailand	11.4

The Netherlands exports large quantities of starch and starch-derived products which account for its relatively high per capita production figure. Thailand, the only less developed country on the list, also reports large exports. The special circumstances in each of these countries is discussed in detail later.

TABLE 12

PRODUCTION OF STARCH AND STARCH-DERIVED PRODUCTS
IN SELECTED COUNTRIES

(millions of pounds)

Country	1966	1967	1968	1969	1970	1971
United States[1]	N.A.	7,650.0	N.A.	7,800.0	8,000.0	N.A.
E.E.C.	N.A.	N.A.	N.A.	3,841.6	4,154.5	4,743.0
Netherlands	N.A.	600.0	900.0	975.0	1,325.8	N.A.
Japan	2.576.5	2,909.3	2,843.2	2,497.1	2,521.4(est.)	N.A.
United Kingdom	N.A.	838.5	849.4	907.7	N.A.	N.A.
Canada	340.8	347.3	378.4	392.1	N.A.	N.A.
Australia	N.A.	183.8	204.1	232.7	280.2	N.A.
Thailand	426.9	547.3	395.6	333.9	398.7	N.A.
World (est.)	19,000.0	19,600.0	19,300.0	21,100.0	22,000.0	22,900.0

N.A. Not available

1 Sales of corn-based products plus estimated potato and wheat starch production.

Source: Trade Commissioner Service reports from overseas posts
Canadian production as in Table
Trade associations

SOURCES OF STARCH

Starch can be extracted commercially from many raw materials including corn, cassava root, potatoes, and wheat. The manufacture of starch from these raw materials usually represents less than 5% of their total usage. Because of the wide availability of raw materials and the interchangeability of starch, the raw material is less important than the establishment of a starch industry using indigenous raw materials.

World production of starch is based largely on corn because this cereal is widely available as an ecomomic source of raw material. In the United States alone approximately 275 million bushels of corn were used by the American corn starch industry in 1970. Corn starch industries also exist in most European and Latin American countries and in Canada. In most cases, these industries use domestically produced corn.

Potatoes follow corn as the most important source of starch. The Netherlands, Japan, France, and Poland are important producers of potato starch. While the situation is unclear in Poland, government policies in Japan, the Netherlands, and France have encouraged the production of starch from potatoes at the expense of more economical raw materials such as corn. Small quantities of potato starch are produced in North America.

Starch is produced from wheat in several countries including Australia and New Zealand where it is the major source. In North America small quantities of wheat starch are produced; the higher cost of wheat compared to corn as a raw material and the demand for wheat gluten (a joint product in the separation of starch from wheat) have limited production. Several European countries also produce small quantities of wheat starch.

The cassava plant, which originated in South America, has spread to many other parts of the world. The major countries producing cassava are Brazil, Thailand, Indonesia, Madagascar, Malaysia, the Philippines and some African countries. The plant is known as manioca, yuca, or cassava; the starch is known as tapioca. The starch occurs in the tuberous root which consists largely of starch (32%) and water (65%) with small amounts of protein, fat, fibre, and ash (all 1% or less). Starch separation is simple and inexpensive, and generally is carried out as a rural industry. In most areas of production, the cassava root serves as a dietary staple. Except for Thailand only a small proportion of cassava root production actually enters the starch industry.

WORLD TRADE

Import tariffs of one to two cents per pound which are applied by many countries constitute a formidable barrier to trade in starch and starch-derived products. As a result, world trade approximates 7.5% of production with major exports being recorded by the Netherlands, and Thailand. The United Kingdom, United States, West Germany and Japan are the principal importing countries. The pattern of trade for these and other countries are shown in Tables 13 and 14.

Tapioca and potato starch each account for approximately one third of world trade in starches. Although corn starch is the largest volume starch produced, its export opportunities are limited by the existence of corn milling industries in many countries.

Starch and starch-derived products imported from the United States are very competitive in Canada. The proximity of the Canadian market gives American starch producers an advantage over exports from other countries. In addition, access to abundant quantities of less expensive raw materials

TABLE 13

EXPORTS OF STARCH AND STARCH-DERIVED PRODUCTS
BY MAJOR EXPORTING COUNTRIES

(millions of pounds)

Country	1966	1967	1968	1969	1970
Netherlands	N.A.	246.1	281.9	426.6	566.3
Thailand	341.5	437.9	316.5	267.1	318.9
West Germany	N.A.	107.0	129.8	141.3	134.7
United States[1]	126.3	119.7	154.1	145.1	112.6
Brazil	106.2	41.7	27.0	133.4	N.A.
France	N.A.	N.A.	20.9	74.3	44.7
United Kingdom	N.A.	7.1	11.2	9.2	36.3
Canada[2]	-	-	-	-	-

N.A.

N.A. Not available

1 Starch sweeteners not included.

2 Less than one per cent of domestic production.

Source: Trade statistics from individual countries.

TABLE 14

IMPORTS OF STARCH AND STARCH-DERIVED PRODUCTS
BY MAJOR IMPORTING COUNTRIES
(millions of pounds)

Country	1966	1967	1968	1969	1970
United Kingdom	452.4	421.1	495.0	526.4	499.6
United States[1]	400.8	341.1	230.0	226.6	236.4
Japan	N.A.	202.0	179.9	170.3	156.6
West Germany	N.A.	87.0	107.2	146.8	156.6
Canada	71.0	75.2	73.8	86.9	78.0
France	N.A.	N.A.	22.4	25.1	47.2

N.A. Not available

1 Starch sweeteners not included

Source: Trade statistics from individual countries.

and economies of scale give them an added advantage over Canadian manufacturers.

REVIEW OF SPECIFIC COUNTRIES

Canadian imports of starches and starch-derived products from several countries are of special interest. For this reason a brief description of the starch industries in the United States, the Netherlands, Thailand, and Brazil is included below. Japan and Australia are also discussed for reasons outlined in the description of their starch industries.

(1) United States

Over 90 per cent of the starch produced in the United States is produced by the wet corn milling industry which is comprised of sixteen plants. Table 15, which provides a breakdown of the sales of corn starch based products in 1969 and 1970, shows that approximately 60% of starch production is used for food purposes, chiefly starch sweeteners and 40 per cent for non-food purposes, chiefly mill starch, modified starches, and dextrines. Small quantities of starch are also produced from domestic wheat and potatoes.

Trade in starch and starch-derived products for the U.S. are shown in Table 16. U.S. exports of starches fluctuate markedly from year to year, but usually average about three per cent of starch production. Canada and the United Kingdom are the major markets for these exports. Sizeable quantities of tapioca starch are imported from Thailand and Brazil on a duty-free basis. Potato starch imports are hampered by a 2.5 cents a pound duty. Most of the U.S. dextrine imports come from the Netherlands and carry a 3.0 cents per pound duty.

TABLE 15

ESTIMATED SALES OF CORN STARCH DERIVED PRODUCTS IN THE U.S.A.

(million pounds)

	1969	1970
Mill Starch	1,700	1,620
Acid Converted Mod. Starch	300	340
Oxidized Starch	150	160
Other Modified Starch	490	490
Pregelatinized Starch	100	100
Grits	50	50
Package Starch	70	70
Dextrine	160	150
Dextrose	1,190	1,210
Corn Syrup	3,150	3,330
C.S.U. in Mixed Syrups	130	130
Miscellaneous Refinery Products	190	190
TOTAL	7,680	7,840
Bushels of corn basis (millions)	210	215

Source: Trade Association

TABLE 16

UNITED STATES IMPORTS AND EXPORTS OF STARCHES AND STARCH PRODUCTS

(million pounds)

IMPORTS	1960/64	1965	1966	1967	1968	1969	1970
Cassava flour, starch, & tapioca	257.7	358.0	340.6	304.0	193.7	195.0	198.7
Arrowroot & Sago (crude & refined)	5.3	4.9	3.0	3.5	3.4	2.9	3.4
Potato Starch	10.0	28.5	1.5	1.4	1.1	.3	2.8
Other Starches	32.0	29.1	21.9	6.8	4.6	2.9	3.7
Dextrine	24.3	25.4	33.5	25.2	27.0	24.8	27.5
TOTAL	329.3	445.9	400.5	340.9	229.8	226.4	236.1
EXPORTS							
Corn Starch	55.2	69.5	71.3	64.7	76.5	59.8	52.1
Other grain starches	9.6	10.4	13.5	11.3	16.9	22.5	14.5
Vegetable starches n.e.c.	7.8	5.2	3.6	3.1	5.8	10.5	1.8
Corn syrup unmixed (excluding pharm. and syrup for table use)	20.7	15.4	13.8	15.4	17.9	25.3	15.4
Refined corn sugar or dextrose (excluding pharmaceutical)	31.6	21.5	24.1	25.2	37.0	27.0	28.3
TOTAL	124.9	122.0	126.3	119.7	154.1	145.1	112.6

Source: Bureau of the Census, United States Department of Commerce, Washington, D.C. 20233. Assembled by and reproduced for Corn Refineries Association, Inc., 1001 Connecticut Avenue, N.W., Washington, D.C. 20036.

(2) The Netherlands

Starch produced in the Netherlands is manufactured from imported corn and domestically produced potatoes. Total production has more than doubled from 600 million pounds in 1967 to 1,325 million pounds in 1970. This gain is attributed to increasing demand in domestic and foreign markets.

Potatoes account for over 80 per cent of the starch production in the Netherlands. Starch potato farmers usually obtain yields of 35 to 40 metric tons per hectare. There is a rigid crop rotation whereby farmers may not use the same land for starch production in the following year. There are, therefore, no farmers exclusively producing starch potatoes. Virtually all starch potatoes are produced within 15 miles of the processing plants. Storage is provided at the farm, and transportation is organized by the factories in order to keep costs at a minimum.

Dutch starch potato farmers receive approximately Cdn. $25.23 per metric ton of potatoes. However, because of a government subsidy program the actual cost to potato starch processors is calculated at CDN $15.04 per metric ton (Appendix B). This pricing arrangement and the use of high starch varieties of potatoes explain the predominance of potato starch in the Netherlands.

Production of potato starch is dominated by A.V.E.B.E., a co-operative organization which accounts for over 80 per cent of the production of potato starch and operates eleven plants.

Exports of starch by the Netherlands more than doubled in the four year period 1967 to 1970. Table 17 shows total starch exports growing from 246.1 million pounds in 1967 to 566.3 million pounds in 1970. Potato starch gained 308% during the period and accounted for most of the increase.

TABLE 17

STARCH EXPORTS BY THE NETHERLANDS -- 1967-1970

(millions of pounds)

	1967	1968	1969	1970
Corn Starch	98.6	102.5	90.5	114.4
Potato Starch	145.5	177.4	333.4	448.7
Rice Starch	2.1	2.0	2.4	2.9
Other	-	-	0.3	0.5
TOTAL	246.1	281.9	426.6	566.3

Large quantities are exported to Britain where it enters at a zero tariff rate vs. 10% on corn starch. Also, prices received in the British market are usually better than those obtained in other markets.

(3) Thailand

The root of the cassava plant is the raw material for starch production in Thailand. Approximately three million metric tons of cassava root is produced annually on (approximately 332,000 acres) mostly small farms. The root is harvested and processed to obtain tapioca starch or a meal product. Approximately 3000 million pounds of cassava products, representing 75 per cent of Thailand's tapioca starch production, is exported. (Table 18) It is exported chiefly to the United States and the meal is exported as a livestock feed chiefly to European countries.

About 180 firms produce tapioca starch and of these only 14 use modern technology. Only unmodified starch was produced in Thailand until recently when a new plant began producing modified starches chiefly for the export market.

TABLE 18

TAPIOCA PRODUCTS EXPORTED BY THAILAND

1966 to 1970

(millions of pounds)

Year	Starch	Meal	Other	Total
1966	341.5	145.0	238.1	724.6
1967	437.9	385.4	155.5	978.8
1968	316.5	856.9	73.2	1,246.6
1969	267.1	1,659.0	98.7	2,024.8
1970	309.3	2,566.3	27.9	2,903.5

Source: Bank of Thailand/Dept. of Customs

The main advantage of Thailand starch in foreign markets is the low cost of the product. Tapioca starch has managed to penetrate overseas markets because of its ability to sell at competitive prices in foreign countries after absorbing long distance freight charges and tariffs. With the addition of modified starches to its selling list, Thailand may become more competitive in its search for export markets. On the other hand, low starch prices in the United States and an import quota in Japan are currently restricting exports of tapioca starch to Thailand's two major outlets. In addition the trend toward high ocean freight rates may be an inhibiting factor in selling to them and other countries.

(4) Brazil

Brazil is included in this review because Canada imports substantial quantities of Brazilian starch in some years.

Both corn and tapioca starches are produced in Brazil from domestic supplies of corn and cassava root.

Statistics regarding the starch industry in Brazil are not available but it is known that this country is the world's largest producer of cassava root. Although approximately three-fourths of the production is used for food, large

amounts are also processed into tapioca starch for use in Brazilian industries and for export. Although considerable quantities are sold in Canada the largest proportion is exported to the United States. As in Thailand, tapioca starch is principally produced by many small producers using simple production methods.

Corn starch is manufactured by some ten firms. The most important producer, a subsidiary of a large U.S. corn starch manufacturer, controls 65 per cent of the market. Most of this production is sold domestically but some is exported to the U.S. and, from time to time, to Canada also.

An 80 per cent ad valorem import duty on all starch imports and currency restrictions protect the domestic industry from foreign competition.

(5) Australia

The starch industry in Australia is of interest to Canada because it is based on wheat. The markets for Australian flour declined during the late 1950's leaving the flour millers with under-utilized capacity. This led to the development of processes for the separation of starch and gluten from wheat flour. There are approximately 10 starch producers in Australia; one uses corn and all the others use wheat flour as the raw material.

The Australian Wheat Board controls the sale of all wheat produced - approximately 500 million bushels annually. Domestic prices are differentiated on the basis of use; approximately A$1.79/bushel for human use, A$1.49/bushel for industrial and A$1.29/bushel for stock feed. Flour prices are also controlled; human use A$108.88/short ton, f.o.b. Sydney, and industrial use A$93.00/short ton. Wheat starch producers are charged industrial prices.

A number of the wheat starch manufacturers are part of an integrated milling, starch, baking, animal feeds complex. Some starch manufacturers use a simplified milling system for the flour used in their separation process.

Wheat starch and gluten are joint products and the markets for them must balance out in a specific ratio. The major uses of wheat gluten are as a bread improver and in pet foods. The usage in pet foods has increased sharply and the outlets for starch have not grown proportionately. As a result domestic starch prices are at low levels (e.g. A$5.75 per cwt. delivered). The current price for wheat gluten is 28 cents per pound delivered.

Australian exports of starches are less than 3 per cent of annual production. Because of lower international prices for wheat, exports of wheat starch are eligible for an export rebate based on an arbitrary standard recovery from wheat flour of 64 per cent starch. High tariffs and transportation costs exclude imported starches from the Australian market.

(6) Japan

Although Japan is not considered as a potential market for Canadian starches or a potential supplier of starches to Canada, the Japanese starch industry is considered important because of the development and use of new technology for starch sweetener production.

Starch production in Japan increased from 1,670.9 million pounds in 1960 to 2,521.4 million pounds in 1970 (Table 19). Domestic sweet and white potatoes and imported corn and wheat are used in manufacturing starch. Declining raw material supplies has caused sweet potato starch production to decrease while production from corn has been increasing. Wheat starch production decreased in the early 1960's when new processes for producing monosodium glutamate led to the displacement of gluten by more economic raw materials.

TABLE 19

STARCH PRODUCTION IN JAPAN - 1960 to 1970

(millions of pounds)

Year	Sweet Potato Starch	White Potato Starch	Wheat Starch	Corn Starch	Total
1960	1,044.7	348.2	242.4	61.7	1,697.0
1961	1,157.1	374.7	242.4	79.3	1,853.6
1962	1,337.8	286.5	176.3	178.5	1,979.1
1963	1,631.0	330.6	154.3	308.6	2,424.4
1964	1,432.6	396.7	121.2	484.9	2,435.4
1965	1,212.2	551.0	132.2	650.2	2,545.6
1966	1,190.2	286.5	185.1	815.5	2,473.0
1967	1,091.0	458.4	154.3	1,146.1	2,849.8
1968	808.9	705.3	132.2	1,124.0	2,770.4
1969	581.9	540.0	132.2	1,188.0	2,442.0
1970	495.9	540.0	132.2	1,287.1	2,521.4

Source: Ministry of Agriculture and Forestry (Japan)

TABLE 20

STARCH SWEETENER PRODUCTION IN JAPAN - 1963 to 1968

(millions of pounds)

Year	Sweetener Production	
1963	1,201.9	(1,336.9)
1964	1,215.1	(1,346.8)
1965	1,274.3	(1,408.5)
1966	1,261.6	(1,400.4)
1967	1,319.1	(1,456.2)
1968	1,693.0	(1,884.6)

Note: Figures in ( ) show amount of raw material starches used.

Source: Ministry of Agriculture and Forestry (Japan)

Corn starch production, which is relatively new in Japan, already accounts for half of the production. This segment of the industry is based on large-scale processing methods. Corn import privileges are allocated to corn millers under a corn import quota system; the government allocates a portion of the import quota to potato starch users as a means of ensuring utilization of domestic potato production. Potato starch is produced chiefly by small manufacturers using simple equipment.

Production of starch sweeteners is shifting from acid to enzyme hydrolysis. Total production from both types increased steadily during the mid-sixties from 1,201 million pounds in 1963 to 1,693 million pounds in 1968 (Table 20). It is interesting to note that starch sweeteners accounted for 25.2 per cent of total sweetener production in Japan in 1969 while the comparable percentage in Canada was 7.4.

Japanese exports of starches are less than one per cent of production and imports of starch products were 6 per cent of starch production in 1970 (Table 14). The chief source of imported starch is Thailand.

SECTION V: STARCH CHEMISTRY & TECHNOLOGY

STARCH CHEMISTRY & TECHNOLOGY

The first portion of this chapter discusses the chemistry and technology pertaining to starch products and the modification of starch. The second section is devoted to consideration of these subjects for starch-based sweeteners. This division has been made in order that the special situations pertaining to each may be identified and discussed without risk of confusing inter-relationships.

STARCH

Summary of Properties of Unmodified Starch

Pure isolated starch is a white, odourless, tasteless solid. Chemically it consists of two components: amylose, a linear or straight chain polysaccharide, and amylopectin, a branched polysaccharide. Both polysaccharides are built up entirely from D-glucose units (more precisely D-glucopyranose units).

Starch occurs widely in the plant kingdom in the form of granules which differ in size, shape and general physical properties from plant to plant. It is the molecular organization within the granule as well as the chemical characteristics of the amylose and amylopectin components which control the important physical properties such as swelling power and gelatinization temperature.

In the natural state the starch granule is a discreet particle held together by a network of associated molecules. The associative forces (known as hydrogen bonds) occur mainly between the amylose and amylopectin molecules and absorbed water within the network. Normally a starch granule contains 10-17 per cent reversibly absorbed water depending upon source and atmospheric conditions.

On heating in water starch granules at first take up water without any change in the typical granule appearance. For each type of starch, at a certain critical

temperature range (gelatinization temperature) the granules swell to many times their original volume with a concomitant large and rapid increase in viscosity and transparency of the suspension. As the temperature is raised further, the starch granules continue to swell and there is a parallel increase in starch solubility, paste clarity and paste viscosity. These properties vary considerably between different starches. As swelling continues, solubles (mainly amylose) are leached from the granules into the surrounding medium, and a network of swollen granules, intergranular regions and leached amylose builds up. Where the supply of water is limited the swollen granules eventually occupy the whole volume and no "free" water exists between the granules. Most fundamental studies of starch swelling normally are concerned with situations of excess water and it should be remembered that many of the practical systems, particularly in foodstuffs, are ones where water is limited.

Further excessive heating can lead to breakdown of the balloon-like structure of the swollen granules which will result in decreased viscosity. The swollen starch is also extremely subject to similar breakdown under mechanical shear. These phenomena are conveniently visualized on an "Amylograph" curve which demonstrates the sudden rapid increase in viscosity during gelatinization, subsequent further swelling increases, followed by a loss of viscosity at higher temperatures under mild shearing action. The last part of these curves demonstrate the setting of the starch to a gel and the phenomena of retrogradation, or setback, in which starch molecules re-associate. This process may end in "weeping" (separation of water), formation of films and precipitates, and loss of paste clarity. The different behaviour of some different starches (natural and modified) are indicated in Charts 4, 5 and 6 and some further details are tabulated in Tables 21 and 22.

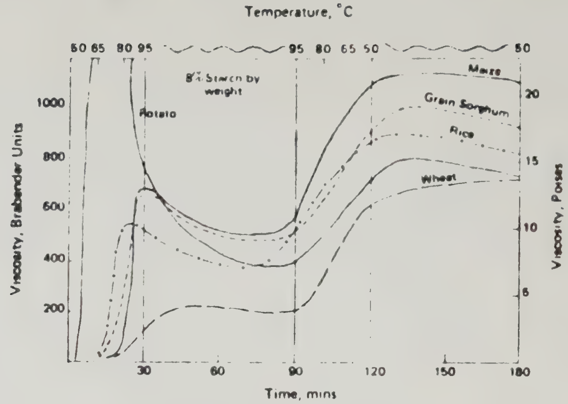


CHART 4. Pasting curves for starches.

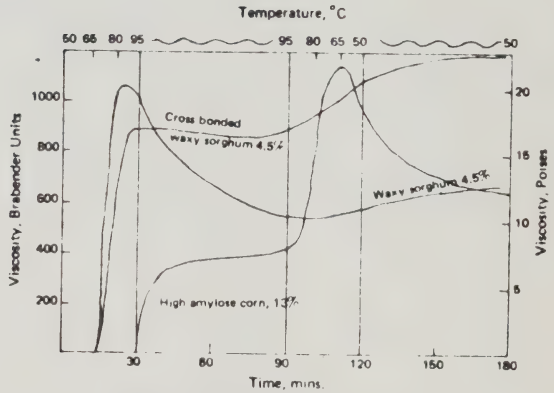


CHART 5. Pasting curves for waxy, cross linked waxy, and high amylose starches

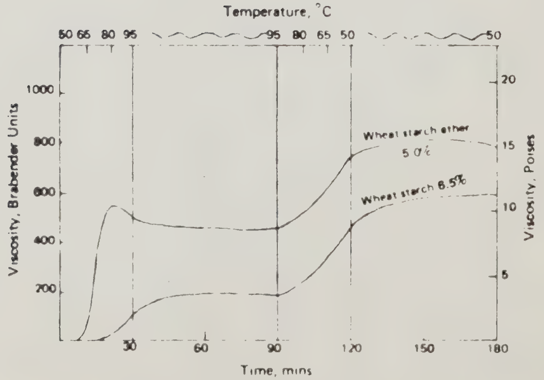


CHART 6. Effect of etherifying common starches.

Source: J.W. Knight-The Starch Industry.

TABLE 21

PROPERTIES OF SOME STARCHES

Source	Barley	Oats	High Amylose Corn	Wrinkled Pea	Smooth Pea	Saponaria Vaccaria (Cow Cockle)	Canary Grass	Rye
Type	Cereal	Cereal	Cereal	Legume	Legume	Weed	Grass	Cereal
Granule size (Microns) (Average	20	25	25	40	30	0.5-1.6	2.5-5.0	
Granule shape	Round	Round	Round	Compound	Oval	Round	Polygonal	
Amylose/Amylopectin ratio	22/78	27/73	52/48 some up to 80/20	66/34	35/65	22/78 (approx)	25/75 (approx)	23/77 (approx)
Gelatinization temp.range °C	59-64	-	85-87	98	98	60-65 (approx)	85-92 (approx)	57-70
Swelling power (95° C)	-	-	6	6	-	20 (approx)	10 (approx)	

Source:

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TABLE 22. PROPERTIES OF COMMERCIAL STARCHES

Type of Starch	Corn (Cereal)	Wheat (Cereal)	Rice (Cereal)	Grain sorghum (Cereal)	Waxy Corn (Cereal)	Tapioca (Root)	Potato (Tuber)	Sago (Pith)
Granule size	Average 15 Smallest 5 Largest 25	Two fractions 2-10 20-35	Variable 3-8	Average 15 Smallest 5 Largest 25	Average 15 Smallest 5 Largest 25	Average 20 Smallest 5 Largest 35	Variable 15-100 Egg-likewith striations like oyster shell	Variable 20-60 Egg-like with some truncated forms
Granule shape	Round, polygonal	Round, elliptical	Polygonal, occurring in clusters	Round, polygonal (as corn)	Round, oval indentations present			
Pattern under polarized light	Black cross	Black cross	Indistinct because of small size	Black cross	Black cross	Black cross	Irregular black cross	Irregular black cross
Approx. Amylose/ amylopectin content	26/74	25/75	17/83	26/74	1/99	17/83	24/76	27/73
Gelatinization temperature range °C	62-74	52-64	61-78	68-75	63-72	52-64	56-69	60-72
Total lipid content approx. %	0.4	1.0	0.4	0.4	0.3	0.1	Very low	Very low
Paste clarity	Opaque	Opaque	Opaque	Opaque	Translucent	Translucent	Translucent	Translucent
Paste texture	Short, heavy body	Short, heavy body	Short, heavy body	Short, heavy body	Long, stringy fluid body	Long, stringy fluid body	Long, stringy fluid body	Long, stringy fluid body
Paste strength under mechanical shear & prolonged heat	Medium	Medium	Medium	Medium	Low	Low	Low	Medium/low
Paste Viscosity	Medium, pronounced set-back	Medium/low pronounced set-back	Medium/low pronounced set-back	Medium, pro-nounced set-back	Medium/high no irrever-sible set-back	High, low set-back	Very high, moderate set-back	Medium/high moderate set-back
Taste & odour	Low	Low	Low	Low	Low	Fruity	Slight cucum-ber-like	Low
Swelling power(95°C)	24	21	19	22	64	71	1,000	97

Source: The Starch Industry by J.W. Knight (1969) Pergamon Press.
Starch Chemistry and Technology. Eds. R.L. Whistler and E.F. Paschall. Vol I (1965) Academic Press.

A number of complex factors affect the swelling characteristics of starch, and the structure and behaviour of the starch granule is perhaps the research area of greatest challenge to the starch scientist. Some features of particular importance are the size and shape of the granule, the crystalline nature of the starch, the amylose/amylopectin ratio, the molecular weight distribution, the distribution and degree of branching of the amylopectin and the amount and type of impurity present.

Some fundamental principles may be followed which allow general predictions to be made. Thus, since swelling represents a disruption of intermolecular forces, factors which reduce these forces will result in an increased swelling power and lower gelatinization temperature. Conversely, factors which increase the intermolecular forces, increase the gelatinization temperature and decrease the swelling power.

Thus the effect of certain fatty compounds in corn starch is to decrease swelling power by formation of insoluble complexes with the linear fractions of starch. Conversely, phosphate in potato starch breaks up the regular interactions between molecules resulting in low gelatinization temperature and high swelling.

High amylose starches are predominantly composed of linear molecules showing a high degree of association and resistance to gelatinization. The amylose content of a number of starches is shown in Tables 21 and 22. The degree of polymerisation (D.P.) of amylose is very variable, depending upon source and method of extraction, but most figures fall between 1,000 and 3,000. The linear amylose molecule may be dispersed, partially at least, into solution, but on ageing, gradual alignment of the molecules leads to the formation of insoluble particles. This retrograded amylose is difficult to redissolve. A rapid cooling results in a more open network of aligned molecules to produce a gel.

The amylopectin, or branched portion of the starch, and the virtually sole component (99%) of true waxy starches, has very different properties. It is a more complex molecule and the structure is still not fully defined. Thus, although the average chain length of the branching is known, the detailed distribution and organization is not. Recent fundamental research on the action of certain enzymes seems destined to reveal some of these important details. The average chain length of most amylopectins is about 20 (e.g. Potato, 24; Wheat, 19; Corn, 23; high amylose corn, 28). D.P.'s as high as 10^6 have been reported. Many amylopectins contain small amounts of bound phosphate. Freeze dried amylopectin disperses readily in water and shows typical starch sensitivity to extremes of pH, and mechanical shear. There is little tendency for the solutions to retrograde, although commercial waxy starches, particularly concentrated pastes, may do so.

Thus, the properties of any starch will be very dependent on amylose/amylopectin ratio.

Starch Modifications in Commercial Use

Most of the starch consumed in Canada has been modified in some fashion. The manufacture, properties and use of the modifications produced commercially have been described elsewhere in this report. The types of modification may be classified as follows:

1. Physical modification

   Dried starch (2-3% moisture) and pregelatinized starch

2. Chemical modification

   a) Degradative reactions - hydrolyzed starch (dextrose, glucose syrups and thin boiling starches) and dextrines.

   b) Oxidizing reactions - Hypochlorite oxidized starches

c) Substitution reactions - Esters, such as acetates and phosphates, and ethers such as the hydroxalkyl starches, carboxymethyl starch and cationic starches

d) Cross-linking reactions - Such as certain phosphated starches

Apart from the degradative reactions, most of the chemical modifications of starch that are used commercially essentially serve just two functions. The reactions either reinforce or disrupt the intermolecular forces within the starch granule, and alter the viscosity and other pasting properties accordingly. Thus cross-linking a waxy starch a) changes the "long" or stringy texture to a more pleasant "short" texture, b) stabilizes the paste against breakdown from excessive mechanical shear, heat or acidity and c) gives a starch of higher viscosity. Substituted starches exhibit reduced gelatinization temperatures, higher peak paste viscosities, reduced setback and higher paste clarity. A combination of cross-linking and substitution may be used commercially to combine various desired properties. Hypochlorite oxidation of starch has effects rather similar to substitution reactions (disruption of the intermolecular forces within the starch granule) but also involves depolymerization.

Research and Development

Amylose and amylopectin are just two examples of a large family of molecules known as polysaccharides. A great variety of physical, chemical and physiological properties are exhibited by these molecules. Thus cellulose, composed entirely of D-glucose units in a slightly different mode of linkage than in amylose, is an inert, insoluble and structurally valuable polysaccharide. In theory, cellulose could rival starch as a source of glucose but, as yet, suitable hydrolytic methods have not been developed.

At the other end of the scale is, for example, the soluble polysaccharide heparin, which is highly reactive both chemically and physiologically. All of these differences are related, in an as yet unknown fashion, to differences in sugar units, modes of linkage, substituents, degrees of branching etc. Computerized model-building[1], X-ray diffraction studies[2], nuclear magnetic resonance studies[3], and a variety of other methods for determining structure and understanding physical properties such as gel formation[4] must be considered important areas of research. More precise knowledge of factors controlling physical and chemical properties, in conjunction with new controlled methods of synthesis and modification (as opposed to present methods which are largely random) will have far-reaching effects on the starch industry. Developing such control over the raw material, starch, may help the industry become more competitive in the field of synthetic polymers.

Enzymes

Studies of starch degrading and synthesizing enzymes have importance to the brewing industry and glucose production and may provide further insight into the structure and properties of the starch granule[5]. Recent work has led to revised ideas about the structure of amylopectin[6]. The full practical importance of enzyme technology is discussed later.

Sources of Starch and Extraction Methods

Starch is present in many plants, a few of which are indicated in Tables 21 and 22, and a variety of other organisms including bacteria and algae. There does not appear to be any strong commercial interest in sources of starch other than those already in use. Surveys of new sources of starch do occasionally describe starches with interesting properties[7,8], but there seems little

likelihood of such sources assuming commercial importance unless a co-product of interest is found. Thus the development of textured vegetable proteins may eventually influence the choice of crop for starch production. New enzyme processes for glucose production and new techniques in microbiology may also influence preferences. Thus the English company, Rank Hovis McDougall Ltd., has determined that the broad bean is a better carbohydrate source for the micro-biological production of protein than is wheat[9]. A recent patent described a process for separation of starch and protein from pulverized plant materials such as broad beans[10]. A modified Fesca process for separation of protein and starch in wheat flour[11] paid particular attention to the protein concentrate obtained in the process, which could have potential in the textured protein market. The described process also eliminated pollution problems that are encountered in the Martin process for wheat starch.

Processes which alter the economics of starch production wastes may influence the choice of starch source. A potato starch factory produces about 8,750 pounds of wet pulp (80% moisture) for each ton of starch produced[12]. Improved utilization of this waste might make potato starch more economically attractive.

Apparently a commercial starch separation from barley is feasible[13] and new varieties could improve this cereal as a source of starch.

The use of new air classification methods and the elimination of the sulfurous acid steeping stage in corn wet-milling are further developments that could revolutionize the starch industry.

In Australia, most starch is produced from wheat using good quality flours. The starch production is largely dependent on the demand for gluten. Gluten is used to fortify flour from low protein soft wheat in breadmaking[9,13], and

improves the quality of the bread[14]. It has been suggested[9,15] that, using soft wheat, a wheat starch industry will expand in the U.K. based on this outlet for the gluten. The starch could be utilized to produce glucose and fructose-containing glucose syrups. If this development occurs, it could reduce U.K. imports of hard wheat, corn and raw sugar from cane.

Amylose and Amylopectin

High amylopectin (waxy) starches, containing from 95-100% amylopectin are available from certain varieties of corn, sorghum grain and rice.

A similar commercial supply of amylose or high amylose starch is not at present available. Physiochemical methods are available for separation of amylose from amylopectin but are not suited to large scale commercial production. Enzyme methods are more promising and the Japanese[16] report the use of debranching enzymes to produce amylose of D.P. 200-300 and 25-30.

Ultimately the aim must be the production of high amylose varieties of crops. In Scotland a high amylose (40%) variety of barley is being developed for malting[13] and in the U.S.A. considerable progress is being made in the development of high amylose corn[17]. As can be seen in Table 22, the wrinkled pea already has a high amylose content. If it were a reliable source of high amylose (80%) an unusual crop (such as the wrinkled pea) might achieve prominence as a source of starch, particularly if a useful co-product (such as protein) were found. At the NRC Prairie Regional Laboratories, Dr. C.G. Youngs[18] has developed a process for separation of starch and protein from the field pea. The pea starch seems to be particularly suitable for clay-binding in the potash industry. Since a 35% yield of 60-70% protein is obtained in the process and since certain varieties of pea (Table 22) may have a high amylose content, these investigations may produce results of commercial interest.

The most useful properties of amylose would be its ability, particularly after modification, to form strong flexible films for use in packaging material or for coating purposes, and its ability to form filaments.

Starch Modifications

A considerable number of starch modifications, other than those already mentioned, are known but are not, at present, commercially significant. The subject has been reviewed[19]. Alkyl ethers, such as the methyl derivative have been suggested as soil suspending agents and may be used in graft copolymerization of acrylonitrile. Cyanoethyl ethers have been used to give paper and textiles microbiological resistance. Allyl ethers, once heralded as having a great potential, have not been a significant rival to synthetic vinyl polymers which captured the anticipated market. Allyl starches do find some application in lacquers and varnishes and in coating paper and textiles. They have been suggested for use in inks, as a finishing agent for wool and as an additive in acrylic resins.

Starch esters prepared from fatty acids, such as stearates, have been proposed as margarine additives. Half-esters of certain dibasic acids have a number of unusual properties. The polyvalent metal salts, for instance, are extremely hydrophobic suggesting potential uses in talcum powder substitutes, etc.

Inorganic esters of starch include nitrate, sulphate, phosphate and xanthate. The nitrate, one of the oldest known starch derivatives, is produced in the U.S.A. as an explosive but evidently is not used in Canada[20].

Sulphates have been suggested for use in drilling muds. Recently improved methods of manufacture have been reported[21], and further reaction may be effected with alkali to produce anhydro derivatives which may be industrially

useful. Starch phosphates already have had commercial success and di- and tri-esters are effective cross-linkers of starch. Mono-esters are used in gravies, soups, sauces, salad dressings, mustards, pie fillings, and elsewhere, and have excellent freeze-thaw stability. Starch phosphates have an advantage over other modified starches in that the phosphate group is readily utilized by the usual enzyme systems of the gastrointestinal tract. Indeed, most natural starches are substituted to a small extent by phosphate. Some interesting new methods of producing highly substituted starch[21] and cross-linked starch phosphates[22], have recently been reported.

Starch xanthates have not achieved much success partly because of lack of stability. The U.S.D.A. Northern Utilization Research and Development Division have strongly recommended this derivative (and the closely related, more stable, xanthide) as a reinforcing reagent for rubber, with a potential U.S. Market of more than 250 million pounds of starch per year[23]. Other sources[24] suggest that the rubber has poor abrasion resistance and unacceptable water absorption characteristics. The Northern Regional Laboratories have also suggested the use of xanthates and xanthides as wet-strength agents in paper[25]. Very high retention of starch is possible, and both wet and dry strength may be imparted. It has been estimated that at a 15-30 million pound/year production the cost of the xanthate would be about 3 cents/pound above that of the raw starch[26]. However, the derivative seems slow in gaining commercial acceptance.

Dialdehyde Starch, made by oxidation of starch with periodic acid was reported as useful in the tanning industry and to impart wet-strength to papers. At present none of this derivative is being produced commercially. Processes are available for converting dialdehyde starch to a dialdehyde starch with some cationic properties.

Many other derivatives of starch are known[21, 27,28], but the chemical reactions involved in their preparation are often prohibitively expensive. Predicting the commercial value of such products is difficult although certain physical properties may be identified as desirable. Most modifications are essentially substitutions and/or cross-linking and alter the starch properties accordingly. Such developments are unlikely to result in outstanding increases in starch production, and may result in a decreased demand for raw starch (e.g. less cationic starch is required in papermaking than if unmodified starch is used). The need for cost or quality improvements will, however, continue to stimulate industrial research in this area. For instance, a cyanoethyl ether of starch may well prove to be more economic to produce than an acid thinned hydroxypropyl starch, but would serve as well in certain sizing and coating applications[26].

A potentially large new market for starch is in polymers. A fruitful area for research therefore might be in graft copolymerization of starch, and the U.S.D.A. Northern Utilization Research and Development Division have done much in this field in the last few years[29,30]. Graft copolymers with acrylamide, acrylic acid or acrylonitrile may have potential as adhesives, flocculating agents, emulsifiers, casein replacement in paper coating etc.

Starch, and starch-derived glycol glycosides may be incorporated into polyurethanes and other alkyd type resins[31,32]. The greater the incorporation of starch, the lower the cost of these products. The 1971 consumption of alkyds and urethanes in Canada was approximately 50 million pounds.

The development of new and more controlled methods of starch modification should be investigated. Novel applications of enzymes may be a useful approach. CPC International (U.S.A.) possess a number of recent patents[33,34] describing the enzymic production of cyclodextrines and a variety of derivatives of this product.

Modification of flours rather than purified starches may become a useful process since for many purposes a high purity starch is unnecessary. Dry reactions for modification have advantages, particularly in decreasing effluent disposal problems, and preparation of cationic flours and starch by a dry process has been developed[35].

Pollution

Improved pollution control in all aspects of starch production is an important area for research. The starch manufacturers are well aware of this and have already introduced measures of control. Production of certain starch modifications, however, continues to pose an effluent problem.

SWEETENERS FROM STARCH

Sweetness is a generally attractive quality in many foodstuffs. Tradionally a major portion of the demand for sweetness has been met by sucrose. However, there are a number of other sweeteners which may be considered competitive or partially competitive with sucrose; the most important being glucose syrup and dextrose. In addition, the conversion of glucose to fructose has recently become commercially feasible, making possible the production of an invert-like syrup from starch which has assumed new important potential as a sweetener. Technological developments and market potentials for these products are considered in subsequent sections. As potential demand for these products must take into account the competitive position of sugar, this assessment is preceded by a description of Canadian sucrose markets and prices.

Background-Sucrose

Sucrose is a non-reducing disaccharide, commonly known as sugar. It occurs naturally in a large number of

plants, but nearly all commercial sugar is obtained from sugar cane or sugar beets, Sucrose consists of two simple sugars, glucose and fructose, in chemical combination. The two latter sugars may be obtained as a mixture, known as invert syrup, by acid or enzyme treatment of sucrose. Invert syrup is therefore normally considered part of the sucrose business, although invert types of syrup may be produced from other sources as noted above.

Canadian Market for Sucrose

The Canadian market for sugar exceeds 2,000 million pounds per annum. Of this amount approximately 12% is obtained from domestically grown beets and the balance is imported cane. Slightly less than 40% is used in households and the balance is used by manufacturing industries. The proportion used industrially has increased steadily for many years, and in 1969 constituted 61.09% compared to 47.9% in 1959. Details of this growth and the quantities used by major industries are shown in Table 23.

Per capita consumption of sugar in Canada was approximately 105 pounds in 1970. This level is two and a half times the world average of 42 pounds, and slightly more than one pound below consumption in the U.S.A. Canadian consumption exceeds the average level in European countries by more than ten pounds, but falls below the U.K. (110.2) and Australia (117 pounds). Differences in consumption are partially explained by differences in tastes and the availability of substitute sweeteners at competitive prices.

Prices

About two-thirds of the raw cane sugar entering international trade is sold under preferential arrangements such as the U.S. Sugar Act and the Commonwealth Sugar Agreement. The balance, equivalent to approximately 8% of total sugar production, is sold on the free, or world, market.

TABLE 23

CANADIAN SUGAR CONSUMPTION
(million pounds)

		INDUSTRY								CONSUMER
Year	Grand Total	Total	Carb. Bev.	Fruit & Veg.	Conf.	Bread & Bky.	Misc. Foods	Bis-cuits	Other	
1960	1,662	822	181	156	129	114	91	59	91	840
1965	1,961	1,007	219	187	164	126	112	71	129	954
1967	2,029	1,190	293	197	181	152	139	82	145	839
1968	2,112	1,230	301	199	189	139	160	79	164	882
1969	2,091	1,264	308	208	176	131	173	89	179	821

Source: Statistics Canada - Census of Mfgrs. (Sugar Refineries)

Canadian requirements for raw sugar are acquired in this market which is essentially a residual market in which sugar is sold after preferred commitments are met.

Prices in the world market are usually lower than the preferential prices. However, because of its residual nature, the amount of available sugar may vary substantially, and result in rather severe price fluctuations. The Canadian experience has been that the advantage of lower prices in most years more than compensates for the occasional run of high prices.

Canadian refined sugar prices are based upon the London Daily Price (LDP) for free market sugar. By a series of calculations, the LDP for raw sugar is translated into a delivered price in Canada and finally to a refined price. Prices which are usually quoted basis Montreal, Toronto, St. John or Vancouver are subject to frequent changes in reference to movements in the LDP. Sugar users may, however, elect to contract for their requirements with delivery of a specified quantity at a fixed price within a designated period of time.

Under the foregoing pricing methods, annual Canadian wholesale prices at Montreal averaged $8.54 per hundred pounds during the ten years ending 1971. Average prices in an individual calendar year have ranged from $6.62 to $11.05. Monthly prices have shown a considerably greater range, from $18.65 (Nov./63) to $5.65 (Jan./67).

Under the terms of a new International Sugar Agreement which came into effect on Jan. 1, 1969, Canada and other countries agreed to accept a price range for raw sugar of U.S. 3.25¢-5.25¢ per pound f.o.b. Caribbean port. The lower limit is considerably higher than pre-agreement market prices which at times fell below 2¢. As a result of this agreement, domestic refined sugar prices are expected

to level in the range of $9.00-$10.00 per hundred pounds at Montreal.

A more detailed description of the industry may be found in the Report by the Tariff Board on Sugar which is available from Information Canada. (Catalogue No. FT4-146)

Glucose Syrups and Dextrose

The discovery that the acid hydrolysis of starch produces a sweet syrup is said to have been in response to a request from Napoleon, embarrassed at that time by the English naval blockade which was preventing sugar cane entering France. Commercial production first began in the United States in the mid-nineteenth century. The original crude acid hydrolysis methods have developed over the years to today's highly controlled processes involving acid and enzyme technology.

Research and Development

Continuous automated processes introduced in the starch and glucose syrup industries have resulted in increased productivity/man hour. New spray drying techniques and the use of reverse osmosis for purification are recent examples of engineering advances. However, the most important advance in recent years has been the discoveries involved with starch degrading enzymes and the commercial exploitation of the resultant products. Industrially there are three important types of enzymes; beta-amylase, which splits off maltose units from the outer chains of the starch molecules, but stops at branch points; alpha-amylase, which splits chains randomly but cannot attack branch points or maltose or maltotriose; amyloglucosidase (glucoamylase), which splits glucose units from the non-reducing end. These enzymes obtained from a variety of microbiological and plant sources, in conjunction with acid hydrolysis, or alone, can be used to produce an almost infinite variety of products.

Debranching enzymes, such as isoamylase, are beginning to assume commercial importance. New sources of enzymes allowing further control of starch hydrolysis conditions, and products formed, and fundamental studies of the mechanisms of starch breakdown are important areas of research receiving much attention today. The Japanese have been particularly prolific in this area as a result of a concerted, government-backed effort to produce sweeteners from surplus potato starch[36]. A particularly valuable objective might be the production of maltose syrups of higher maltose content than the present 30-40 per cent level[16,37,38].

The development of processes capable of producing high quality glucose syrups from intact cereal grains, or other unpurified starch sources such as flour, intact peas, etc. is feasible if the right enzymes can be found. A number of claims of success have been made[29,40] but no commercial production is known of at this time. An acceptable process of this nature would have considerable commercial potential, particularly if the utilization of the protein remaining after the starch hydrolysis could be improved. A first stage in the development of such processes for glucose syrup production[41,42] is the use of enzyme-enzyme systems which may overcome processing difficulties such as colour formation.

Many new developments in enzyme technology can be expected in the next few years. While it is outside the scope of this report to consider applications unrelated to starch, it should be recognized that developments in enzyme chemistry and technology in areas other than starch may have applications in the starch industry. In the United Kingdom the Science Research Council has selected enzyme chemistry and technology as "an area of science worthy of special encouragement", and a committee has subsequently allocated more than $2.5 million for research[43]. One area of enzyme technology that has received considerable

attention is that of insolubilized enzyme reactors[44,45]. Professor Barker (Birmingham University, England) claims to have developed a number of commercially acceptable systems [45,66]. The most important are based on a simple process involving fixation of the enzyme through titanium to a support such as cellulose. The reported ease of removal of the attached enzyme, the high retention of activity and the low loss of activity (30-40% after six weeks continuous use) make this a potentially outstanding method.

Rank Hovis McDougall Ltd. expect to be using insoluble enzyme reactors in the next five years[47]. Corning Glass in the U.S.A. also has a number of patents covering enzymes insolubilized on inorganic supports and claims large re-usability factors and high efficiency on insolubilization[48]. They are at the pilot plant stage, as is Professor Barker's group.

In modern glucose plants, enzymes contribute significantly to the cost of production (approximately 25-35¢ per 100 lb. of glucose syrup produced). While a number of factors (e.g. cost of support, re-usability) need to be considered, it seems reasonable to assume that an economically viable process for insolubilization of enzymes will be available in the near future. A useful review of the advantages and difficulties involved in the application of biochemical reactors of all types has been given recently by Lilly and Dunhill[49].

New outlets for glucose syrups are less easily defined than potential new developments in manufacture. In the long term, it is believed by many that starch and glucose will become a raw material for the bulk chemical industry[50]. The literature on reactions of glucose and related carbohydrates is massive, and it would be difficult to identify any successful product beforehand. Nevertheless, certain areas of endeavour are likely to be more rewarding than others. One might be the production of polymers

(of unknown properties) from glucose and its derivatives[51]. Another area of interest is enzymic conversions of glucose. Fructose may be produced enzymically or chemically from glucose, and is of such importance that it is discussed separately in the following section.

Fructose

Although the lower sweetness of glucose compared to sucrose is sometimes an advantage, the ability to produce a sweeter product, such as invert sugar, would allow an expansion of the markets for glucose syrups into areas now held by sucrose. Since fructose is approximately 1.5 to 2.0 times as sweet as sucrose, the conversion of glucose syrup (or dextrose) to fructose would seem to offer considerable commercial possibilities if it could be done on a competitive basis. Chemically, the combination of one molecule of fructose with one molecule of glucose with the elimination of one molecule of water, gives sucrose. No commercially feasible methods exist for this process, but the reverse, hydrolysis of sucrose to a mixture of glucose and fructose known as invert syrup, is well known. Many of the uses of sucrose involve media of low pH which eventually results in conversion of the sucrose to invert syrup.

Manufacture

Production of pure fructose is small at present and mainly confined to the pharmaceutical and fine chemicals industries. However, the Finnish Sugar Company Ltd., have recently been marketing fructose ("Dietade" in the U.K.) at $1.80 per pound as a dietetic sweetener and for diabetics. Details of their manufacturing process are not published but involve separation of fructose from an invert syrup prepared by hydrolysis of sucrose or possibly by conversion of glucose syrup. Separation of fructose from glucose and subsequent crystallization of fructose are not easy on the commercial scale. Most of the numerous patents which

have been registered involve rather complex procedures although a relatively simple process has been described[66] by the West German company Boehringer. The purpose of all of these separations is to obtain the fructose portion since glucose is obtained more easily from starch. In Canada, pure fructose is apparently an imported commodity.

A number of procedures have been developed to remove glucose from an invert syrup by conversion to another product. In one such product, made in the USA by Huron Biochemicals Inc., Illinois, glucose is converted to gluconic acid. The resultant fructose-gluconic acid mixture is also claimed to be palatable and useful dietetically.

Japan and the U.S.A. appear to be the only countries presently manufacturing fructose-containing glucose syrups from starch. The process used is patented in several countries by the Japanese Government's "Fermentation Research Institute". In the U.S.A., the Japanese Agency of Industrial Science and Technology has granted an exclusive license with sub-licensing privileges to Standard Brands Incorporated. The Clinton Corn Processing Company of Clinton, Iowa is currently manufacturing Isomerase(R)100 and the A.E. Staley Manufacturing Co. (Decatur, Illinois) will shortly commence production of Isosweet 100 under the above license.

The Japanese process uses enzymes known as glucose isomerases. In fact these are xylose isomerases adapted to use glucose. The organisms (usually of the Streptomyces genus) are cultivated in a medium containing xylose or xylan. A typical medium consisted of 3% wheat bran, 2% corn steep liquor and 0.024% cobaltous salts[53]. Cells were collected and used as such, without enzyme extraction and purification, to give on the industrial scale a 45-50% yield of fructose from a 50% aqueous solution of glucose.

The exact details of the processes being used in the USA are unknown. Since most of the enzymes reported to date are all produced intracellularly, preparation of

pure enzyme will be costly and thus intact cells are probably used.[54] The substrate is a solution containing over 92% glucose at 60% solids. The reaction is carried out at 70°C and pH 6.5, in the presence of a number of mineral co-factors. Takasaki[53] reported a three day reaction time was necessary for about 45% conversion. Under these conditions considerable colour formation will occur. Refining includes filtration, heating, decolourization and ion-exchange (undesirable ions such as cobalt are thus reduced to acceptable levels). The resultant syrup is clear, slightly viscous and with a sweetness comparable to sucrose when compared at the same dry substance. A typical analysis is solids, 71%; pH, 4.3; ash, 0.05%; nitrogen, less than 0.001%; fructose, 42%; glucose, 50%; other saccharides, 8%.

In Japan a separate patent exists on an essentially similar process developed by the Japanese Food Research Institute. The "isomerase cake" and details of operation are being marketed by Nagasi and Co. Ltd., Japan[55].

Uses

The uses of fructose as invert syrup coincide fairly well with the uses of liquid sucrose, and these products are not distinguished in published statistics. The overall uses of sucrose are shown in Table 23. A variety of mixtures containing equal amounts of glucose and fructose with varying amounts of sucrose are produced. These mixtures are used in many applications including soft drinks, canned goods, confectionery, baked goods, pharmaceuticals, artificial honey. In many uses, pure sucrose effectively reaches the consumer as invert syrup because of the extreme sensitivity of sucrose to heat and acid. Thus, fructose-containing glucose syrups, prepared from starch, would be expected to be in direct competition with liquid sucrose and invert syrups or those uses where sucrose is in solution at some stage of the process.

The uses of pure fructose have been advertized[56] in direct competition with sucrose. However, the market for this solid is small and a number of the claims made or suggested (which includes speedier relief from hangovers) are exaggerated. It is not expected that this sugar, as a purified product, will ever command a large market.

The potential uses of fructose-containing glucose syrups are, however, considerable. The properties of fructose may be summarized as: (a) intrinsically sweeter than glucose or sucrose, (b) the most soluble of the three sugars, (c) crystallizes with difficulty, (d) inhibits the crystallization of glucose (much as glucose inhibits the crystallization of sucrose). Consequently, syrups with higher levels of sweetness and less tendency to crystallize at low temperatures may be produced. The products "Isosweet" and "Isomerose" are claimed to have high sweetness, high fermentability, high humectancy, low viscosity and a clean, non-masking taste. Handling and storage are also easy.

Fructose-containing glucose syrups are thus presently used in the USA[+] in carbonated beverages, fountain syrups and flavour concentrates, fruit juices, pickled products, salad dressings, ketchup, cakes and cookies and a number of other products. The use of fructose syrups in ice cream and ice lollipops could be particularly advantageous since sweetness of fructose increases at lower temperatures and there is less danger of crystallization.

In Canada, in 1968, the soft drink, confectionery, and baked goods manufacturers consumed approximately 708 million pounds of sucrose. A 20[++] per cent inroad into this market by a fructose bearing glucose syrup would have approximately doubled the 1968 glucose production.

\+ Information based on sales literature. Extent of use in these markets unknown, and may just be potential.

++ Not intended as an estimate of potential market.

Research and Development

The history of enzymic conversion of glucose to fructose goes back to 1957, when Marshall and Kooi of CPC International Inc. reported the presence of glucose isomerase in cells of Pseudomonas hydrophilia[57]. Since then a number of reports and patents have appeared[53]. A Canadian patent has been granted to the Japanese Agency of Industrial Science and Technology[58].

As this is an enzyme process, much of the interest in enzyme technology and biochemical engineering discussed in connection with glucose production apply equally well. Thus better sources of enzyme might be found. For instance, an enzyme and micro-organism not requiring toxic co-factors such as cobalt would be an improvement. An enzyme that worked at lower temperature and pH would also be of value. In this connection, methods of insolubilization and immobilization are important[59]. This latter technology could also make production of a purer enzyme more economical, though the present processes do use an enzyme "cake", which may be re-used once or twice.

The alternative to enzymic methods of production are chemical. The isomerization of glucose to fructose by alkali is well known and is one of many of reactions known as the Lobry de Bruyn, Alberda van Ekenstein transformations[60]. A variety of methods essentially based on these transformations have been reported[16,61-5]. All these methods are less specific than the enzyme process and the side reactions produce undesirable components. Consequently none are used commercially at present.

Professor Barker, of Birmingham University has developed a process (patents pending) which uses a chemical catalyst to convert a 30% solution of glucose to a mixture containing only glucose, fructose and small amounts of mannose. Conversions as high as 55% fructose can be achieved. Professor Barker predicts that, with some modifications, this method could be more economical than enzyme methods[66].

Professor Barker also claims to have developed superior methods of separation of glucose and fructose, giving added versatility to this chemical method. The Japanese Fermentation Research Institute are also developing new separation techniques[67].

Fructans (polysaccharides composed of chemically linked fructose units) exist in a number of plants[68]. Some of these plants (Jerusalem artichokes, chicory, dahlias) have long been recognized as potential sources of fructose, but yields, processing methods and other factors have evidently not been commercially encouraging. High sucrose and glucose prices, and research in plant breeding, processing and total utilization of the components of these crops might alter this situation.

Restrictions on the Production of Fructose-containing Glucose Syrups

The major factor restricting the production of fructose-containing syrup is the necessity for this product to compete directly with sucrose. At present the product Isomerose 100 which is approximately equivalent to sucrose in sweetness is selling at U.S. $6.79 per 100 lb. commercial basis, or about $9.50 per 100 lb. on a dry weight basis. This is well below recent prices of sucrose in the U.S.A. ($12-14/100 lb.) In Japan, the margin is slightly less (about $1.60 per 100 lb.). The cost of production, excluding such factors as the cost of the glucose syrup and capital investment, is about $1.50 to $2.00 per 100 lb. [55,69].

There are no specific Food and Drug Regulations concerning the use of fructose-containing flucose syrups, and they would probably be considered much as invert syrup. (see Government Regulations). The product Isomerose 100 has been extensively investigated in toxicity and pathogenicity texts[54] and no evidence of adverse effect in rats, rabbits or pigs noted. However, fructose is reputedly much like sucrose in respect to coronary artery disease and dental caries. Indeed there is a suggestion that it is the fructose which is responsible for the reported increased serum triglyceride level associated with sucrose intake[70].

Some of the physico-chemical and functional advantages of fructose syrups have been discussed. A disadvantage might be their acid and heat instability.

OTHER SWEETENERS

Of other sweeteners, perhaps the most successful were the cyclamates, which possessed no bitter or otherwise unpleasant after-taste. These compounds have now been banned as food additives in Canada and elsewhere because of evidence that they might be carcinogenic. The widespread suspicion of food additives is now particularly strong in the area of artificial sweeteners. Saccharin, long used in dietetic and diabetic foods in Canada (though it possesses a less satisfying taste than cyclamate or sucrose) is now under suspicion in the U.S.A., again as a possible carcinogen, and has been removed from the list of products generally recognized as safe (G.R.A.S. List).

A number of polyhydric alcohols have found use, or are potentially useful, as sweeteners. These are prepared from naturally occurring carbohydrates by single chemical processes and thus have less of the stigma associated with other synthetics. Sorbitol (prepared from dextrose) and mannitol are two such sweeteners, used in dietetic and diabetic foodstuffs.

Xylitol also has potential. Xylitol is prepared by reduction of xylose which can be obtained by hydrolysis of xylan, a polysaccharide found in barley husks, corn cobs, oat hulls, bagasse, etc. Another alcohol of potential is maltitol which would be made by reduction of maltose obtained from starch hydrolysates. This compound has been developed by the Japanese who report its sweetness as about 85-95% that of sucrose[16]. As enzyme technology improves, so the production of high maltose syrups from starch becomes easier and more economical. This would suggest that maltitol should be given a high priority in sweetener research. It is non-digestible and therefore would be useful dietetically and for diabetics. There have, nevertheless, been some reports of undesirable side-effects in volunteer consumers[71]. Despite this, maltitol is already being marketed to the Japanese public under the name "Malbit".

The discovery of sweet tasting compounds is often accidental, since the relationships between flavour and chemical structure are little understood. The aptly named serendipity barries were recently reported[72] as a source of one such sweetener, about 800 times as sweet as sucrose. Other recently reported compounds with sweetener potential were the dihydrochalcones[73], some of which were estimated to be 2,000 times as sweet as sucrose and certain dipeptides such as L - aspartyl - L - phenylalanine methyl ester which was 100-200 times as sweet as sucrose[74]. Many other intense sweeteners are known, but none have been exploited commercially as yet. It is unlikely that a naturally occurring sweetener directly competitive with glucose syrup and available in cheap bulk quantities will be discovered. While a synthetic sweetener with the appropriate properties may be found, consumer resistance to synthetics (as a result of the cyclamate scare) would probably limit its success. The best prospect for the glucose syrup industry would, therefore, be the discovery of a naturally occurring, highly intense sweetener which in small additions would increase the sweetness of glucose to near that of sucrose.

CANADIAN RESEARCH AND DEVELOPMENT

Starch and starch-derived products made in Canada are mainly designed for conventional uses within the paper, food and textile industries. Consequently, the major research activity of starch producers and users is designed to improve these products and their utilization within these industries. Another major area of industrial research interest is in pollution control. Long term research designed to introduce starch into new industries (such as rubber) or develop new products (such as fructose-containing glucose syrups) has not been undertaken.

Apart from the work of Dr. C.G. Youngs (NRC Prairie Regional Laboratories) on starch in field peas, there is no Government starch research at present in progress.

Within the Universities, Dr. N.P. Badenhuinzen, Department of Botany, University of Toronto, has major interests in the development of starch in plants and Dr. R.H. Marchessault, Department of Chemistry, University of Montreal, has interests in crystallization of starch pastes, cross-linked starches and in ion-exchange starches.

SECTION VI: GOVERNMENT REGULATIONS

GOVERNMENT REGULATIONS

Internationally, regulations on glucose syrups vary considerably. Table 24 gives some indication of the situation. Some of these restrictions, both in Canada and abroad, are difficult to understand, since in most cases (for instance chocolate or fruit juice) it would seem best to let the consumer decide his preference. However, in some cases, the restrictions are more apparent than real since they are based on figures requested by the industry.

Medically there seems little evidence to justify restrictions in glucose consumption except as a slimming measure, which applies to most carbohydrates eaten. From certain specific dietary points of view, particularly in connection with serum triglyceride level, there is evidence to suggest that glucose is preferable to sucrose. Glucose may also be less cariogenic than sucrose. These are all areas of some controversy, which need to be resolved by further research.

CANADIAN REGULATIONS

Some definitions used by the Division of Food Additives and Standards of the Food and Drug Directorate are given below, followed by some of the regulations for specific uses in Canada.

Dextrose, for the purpose of these Regulations

(a) shall be the food chemically known as dextrose; and

(b) shall not contain more than 10 per cent moisture.

Glucose

(a) shall be the thick, syrupy, nearly colourless food made by the incomplete hydrolysis of starch or of a starch-containing substance;

(b) may contain sulphurous acid or its salts;

(c) shall not contain more than

(i) 22 per cent moisture, and

(ii) 1 per cent ash; and

(d) shall not contain less than 25 per cent reducing sugars calculated as dextrose on a moisture-free basis.

Glucose Solids

(a) shall be the nearly colourless food made by the incomplete hydrolysis of starch or of a starch-containing substance, and if the glucose is derived from corn, may be called "Corn Syrup Solids";

(b) may contain sulphurous acid or its salts;

(c) shall not contain more than

(i) 6 per cent moisture, and

(ii) 1.25 per cent ash; and

(d) shall not contain less than 15 per cent reducing sugars calculated as dextrose on a moisture-free basis.

(Naming the source of the glucose) Syrup

(a) shall be glucose;

(b) may contain

(i) a sweetening agent,

(ii) a flavouring preparation,

(iii) sorbic acid, and

(iv) sulphurous acid or its salts; and

(c) shall not contain more than

(i) 35 per cent moisture; and

(ii) 3 per cent ash.

Caramel is a food additive permitted as a colouring agent and is limited only by Good Manufacturing Practice. Permitted in unstandardized foods, and a long list of standardized foods including jam, bread, butter, cheese, vinegar, ice cream mix, ketchup, rum and whisky, wine, smoked fish, etc.

LEGISLATION ON GLUCOSE SYRUPS 1970

	Austria	Belgium	Den-mark	France	Germany	Uk	Italy	Nether-lands	Spain	Sweden	Switzer-land	USA	Canada*
Jams	O	X	X	X	O	X	●	O	X	X	X	O	O
Canned fruit	X	X	X	X	X	X	●	O	X	X	X	O	X
Chocolate	●	●	X	O	●	X	O	●	●	X	●	O	●
Ice Cream	X	O	O	O	O	X	O	X	X	X	O	X	X
Fruit syrups	●	O	X	X	●	X	●	●	O	X	●	X	●
Fruit Juices	O	O	X	●	X	X	●	●	O	X	●	X	●
Soft drinks		O	X	O	X	X	O	O	O	X	O	X	X
Sugar confect.	O	X	X	X	X	X	O	X	X	X	X	X	X
Flour confect.	O	X	X	X	X	X	X	X	X	X	X	X	X
Meat		X	X	X	X	X	●	O	O	X	X	O	O
Beers	●	X	X	X	X/●	X	●	X		X	●	X	X

Code: X admitted O admitted with restrictions ● forbidden

* 1972, as indicated by the Food and Drug Directorate

Source: Glucose Syrups and Related Carbohydrates
Eds. G.G. Birch, L.F. Green and C.B. Coulson

In the following regulations for specific uses, the terms dextrine, glucose syrup etc. are used as defined by this report rather than the above Food and Drug Directorate definitions.

Chocolate. The standards for sweet chocolate, sweet chocolate coating, milk chocolate coating, etc. make no provision for using glucose syrup or glucose solids. Any amount of cane sugar may be used, and up to 25% of it may be replaced by dextrose.

Jams and Jellies (both pure and pectin), may contain sucrose, invert syrup, dextrose, or "sweetening ingredient" in a quantity not limited except by % fruit or % solid requirements, but the "sweetening ingredient" cannot be more than 25% glucose syrup dry basis. In fruit preserves or conserves glucose syrup may not be used at all.

Canned and Frozen Fruits may contain glucose syrup or dextrose, amount not limited.

Canned Vegetables may contain dextrose but no glucose syrup.

Ketchup may contain cane sugar or invert syrup or dextrose or glucose syrup.

Canned Beans may contain any sweetener including dextrose or glucose syrup, no limit.

Pickles and Relishes may contain dextrose or glucose syrup, no limit.

Fruit Juices may contain dextrose but no glucose syrup.

Ice Cream. No restriction on glucose syrup or glucose solids or any other sweetener. Same applies to Sherbet and ice milk.

Bread may contain any mount of any sweetener including dextrose or glucose syrup and may contain corn or other starches (dextrinized if necessary) up to 5% on the flour.

Meat Products - Items like sausage, meat loaf, etc. may contain sugar, dextrose, or glucose syrup in addition to a cereal filler, but the finished product when completely hydrolyzed must not show more than 4% reducing sugar. Pure

corn starch is not allowed, although potato starch gets in as a "flour". Essentially the same regulations regarding filler apply to fish and to poultry.

Cheese. Under present regulations, may not contain sweeteners of any kind.

SECTION VII: OUTLOOK FOR STARCH INDUSTRY

OUTLOOK FOR STARCH INDUSTRY

The major factors contributing to past growth in the demand for starch and starch-derived products have been the growth in the industries using these products and technological developments which have generated new demands or increased usage in existing applications. The trend to increased use of prepared foods, which constitutes a partial transfer of demand from the home to factory, has also led to increased industrial consumption. Unfortunately, the demands attributable to each factor cannot be isolated and thus a separate analysis and projection of demand attributable to each factor is not feasible. For this reason, the following assessment of the probable future development of the industry is based upon the total industry picture, augmented by separate forecasts of the potential impact of major technological developments found in special situations such as fructose.

DEMAND IN EXISTING MARKETS

Table 25 contains projections of the future demands for starch and starch-derived products calculated upon five bases. All are extrapolations of demand increases which occurred between the base period, 1957/59, and 1968. The first (Projection 1) projects 1968 volumes of each product group (e.g. starch) by its respective percentage increase of sales between 1957/59 and 1968. Projections 2 and 3 are based on the percentage increase of the individual industries and the major product categories (e.g. Food, Non Food etc.) respectively (see Tables 4-7). All of these projections are calculated on simple percentage increases.

Projections 4 and 5 show the level of consumption which would exist if average year-to-year volume increases realized in the ten years and three years ending 1968 were continued until 1978. As would be expected, these forecasts are significantly lower than the others because they are based upon volumes attained when industries were operating at lower levels.

TABLE 25

FORECAST CONSUMPTION OF STARCH & STARCH DERIVED PRODUCTS
(Million Pounds)

	ACTUAL			PROJECTIONS FOR 1968-1978						
	Avg. 1957/9	1968	1969	1.	2.	3.	Average (1-3)	4.	5.	Avg.(1-5)
Starch	107.8	212.3	237.4	418.1	435.6	423.9	425.9	310.0	330.0	378.5
Glucose	79.6	148.4	148.6	276.7	276.0	267.1	273.3	222.0	218.0	239.4
Dextrose	11.9	17.5	18.0	25.8	28.1	25.8	26.6	24.0	23.0	25.3
Dextrine	14.0	19.0	20.0	25.7	27.4	25.7	26.3	24.0	22.0	24.9
Other	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
	268.3	452.2	479.0	801.3	822.1	797.5	807.1	633.0	648.0	723.1
				(7.7%)	(8.2%)	(7.6%)	(7.8%)	(4.1%)	(4.4%)	(6.1%)

Basis of calculation:

1. $\frac{1968}{1957/9}$ x 1968 using group totals
2. Sum of individual industries projected on '1'
3. Sum of major categories projected on '1'
4. 10 year average physical volume increases added for each year
5. Latest 3 year average physical volume increases added for each year

% not compounded $\frac{\text{10 year \% change}}{10}$

\+ Adjusted by reduction of 41.2 million lbs. in Misc. Foods
7.9 " " " Bakery

Although a case can be made for employing any one of the foregoing projections, or other projections using more sophisticated techniques, past experience has shown that relatively unsophisticated projections have equalled or bettered other methods in accuracy. The Committee has therefore used the average of the first three forecasts as the basis for assessing the future of the starch industry. On this basis, existing markets will require 807 million pounds of starch products in 1978, an increase of 68% over 1969 and 78% over 1968.

POTENTIAL NEW MARKETS

Sweeteners

In respect to new developments and new markets, the Committee believes that fructose bearing syrups offer the greatest opportunity for increased volume. It has been noted that a 20% share of the sucrose used in the carbonated beverages, baking biscuit, and confectionery industries in 1968 would have equalled the 1968 glucose volume of 148 million pounds. Growth projections of these industries suggest that their sucrose requirements will total more than 1,000 million pounds in 1978. Assuming the same 20% ratio, the potential volume for fructose would be 200 million pounds. Whether this volume is achieved will depend to a great extent on the price relationship between fructose bearing syrups and sugar. If fructose bearing syrups can be produced and sold at a lower price than sugar on a sweetening basis, the forecast figure could be exceeded by a substantial margin. On the other hand, a price above sucrose would deter sales of fructose bearing syrups, and possibly hold volume well below the potential.

In the same manner, a large potential exists for dextrose as a substitute for sucrose if sugar prices remain at a level which would permit dextrose to sell at a competitive price on a dry basis. Under these conditions estimates of the potential place it around 100 million pounds per annum. Dextrose and fructose bearing syrups would be used for different purposes and therefore the use of one would not reduce the potential for the other. They could be regarded as complementary

products; if one were to prove unsatisfactory for a given application, the other probably could be used.

Starch

In the starch segment of the industry, the possibility of a significant increase in consumption seems more remote. For a number of years the paper industry was expected to use starch in newsprint production in order to produce a paper for offset printing. Although offset presses are becoming more common, the major papers have continued with the letterpress method using regular newsprint. In addition, recent developments have enabled paper manufacturers to produce offset paper without starch or other additives. Consequently the anticipated large increase in consumption is not expected to materialize.

Another situation with interesting potential is the brewing industry. At the present time, adjuncts used by the industry total about 130 million pounds. Of this amount, approximately 110 million are cereal based; the balance being corn syrup and small quantities of corn. More than 90% of the cereal adjuncts is comprised of corn flakes, grits or meal (similar dry-milling products differing primarily in particle size), and approximately one-half are imported. Corn starch can and has been used as a substitute for these products but it is more costly. Unless dry-milled products increase in price, prospects of capturing a significant volume of business are not considered favourable. The situation is mentioned, however, because of the large volume of imports which could be replaced by starch or, at the least, by Canadian produced dry-milled products. Present imports are equivalent to 1.4 million bushels of corn as starch, or about 1.0 million bushels in the form of corn grits.

Other potential applications include starch as a replacement for casein in the paper industry where approximately 10 million pounds of the latter are used annually as a waterproofing agent. Casein is relatively expensive and new water-

proofed grades of starch may be able to capture a substantial share of this market. New types of starch may also be able to be substituted for carboxy-methyl cellulose (CMC) now utilized in foods as a thickener, suspension or emulsifying agent, or emulsion stabilizer. CMC is also used in the textile industry for sizing. There is no data on total demand but is believed to range up to ten million pounds. Although these applications represent significant starch volume, a separate projection of starch potential has not been made as they are seen as expansions of present applications and included in the basic projection of demand.

RAW MATERIAL REQUIREMENTS IN 1978

Translating the foregoing projections into raw materials, the normal demand for starch products in existing applications is equivalent to 75 million cwt. of potatoes, or 21 million bushels of corn, or 31 million bushels of wheat in 1978. This level is regarded as a minimum. Given a favourable price relationship with sugar, fructose-bearing syrups and dextrose could represent additional demands equivalent to 26 million cwt., 7.2 million bushels, and 10.8 million bushels respectively. Total demand could therefore more than double 1969 levels and, at the least, should be two thirds greater. Details of these projections by product types are given in Table 26.

The benefits which could accrue to Canadian manufacturers from increased demands will depend to a great extent upon their ability to meet these requirements from their own production. To the extent that they are successful in holding imports at present or lower volumes, both Canadian manufacturers and agricultural producers will benefit.

It has been noted that price is one of the dominant factors determining whether the product will be imported or purchased domestically. If Canadian manufacturers can meet competitive prices, they will be able to maximize their growth. One means of attaining lower costs is to raise the starch content of the raw material, thus increasing the yield and red-

ucing the cost/pound of raw starch. Opportunities in this area are examined in the following section.

TABLE 26

ESTIMATED RAW MATERIAL EQUIVALENTS
STARCH AND STARCH-DERIVED PRODUCTS

(Millions)

1978

Present Markets	Potato	Corn	Wheat
Starch	42.6 cwt.	11.9 bu.	17.7 bu.
Glucose	24.0	6.7	10.0
Dextrose	3.1	0.9	1.3
Dextrine	2.7	0.7	1.1
Other	2.6	0.7	1.0
	75.0	20.9	31.1
Special Situations			
Fructose	17.6	4.8	7.3
Dextrose	8.5	2.4	3.5
	101.1	28.1	41.9

SECTION VIII: POSSIBILITIES FOR INCREASING THE STARCH PRODUCTION OF THE PRINCIPAL CANADIAN FIELD CROPS

POSSIBILITIES FOR INCREASING THE STARCH PRODUCTION OF THE PRINCIPAL CANADIAN FIELD CROPS

CEREAL GRAINS

Cereal grains can be defined as those members of the grass family, Graminae, grown for their edible seeds. They include corn, barley, grain sorghum, millet, oats, rice, rye and wheat. Although the potential of grain sorghum and millet is being examined[83], they, and rice, are not grown extensively in Canada. These three crops are not adapted for Canadian conditions and therefore will not be considered. Major attention will be devoted to wheat and corn, the main sources of starch derived from cereals in this country and to barley, oats and rye. Consideration will be given to their distribution, chemical composition and the properties of their starches and related constituents, and to the possibility of improving their starch quantity and quality by plant breeding methods.

Production figures for the major cereal grains grown in Canada are shown in Table 27. These figures do not indicate production potential, since they contain data from years in which there were controls of wheat production and encouraged cut-back on other crops. A report by Clark et al. on ethanol production for fuels[75] contains figures indicating maximum production attainable from the major Canadian crops. Obviously, current production is well below potential. If economic incentives were given to produce more biomass energy, the figures presented in Table 27 could be at least doubled within a few years.

The figures (Table 27) reveal that, although the greatest proportion of the cereal grains is produced by the Prairie provinces, all provinces except Newfoundland show some capacity for production. Oats, barley and spring wheat are grown in all nine provinces. Durum wheat is produced mainly on the prairies while Ontario produces all of the soft white winter wheat. Approximately 200,000 acres of hard red winter wheat are grown annually in western Canada (included in spring wheat acreage, Table 27). Corn production is limited largely to Ontario with some in Québec and limited amounts

TABLE 27

AVERAGE (1967-1971) ACREAGE, YIELD AND PRODUCTION FROM THE PRINCIPAL CANADIAN FIELD CROPS[1]

Crop and area	Acres	Yield bu/acre	Production bu.
Corn			
Canada	1,068,580	81.9	87,544,000
Québec	62,680	80.2	5,059,800
Ontario	1,001,000	82.2	82,265,200
Manitoba	4,900	42.2	219,000
Alberta	1,000	50.0	50,000
Barley			
Canada	10,347,200	38.3	404,588,800
Prince Edward Island	18,400	42.9	787,000
Nova Scotia	5,940	40.0	244,400
New Brunswick	7,840	38.8	256,800
Québec	22,220	37.7	839,000
Ontario	325,000	51.3	16,735,800
Manitoba	1,408,000	37.1	53,900.000
Saskatchewan	3,432,000	37.4	135,800,000
Alberta	4,966,000	38.2	190,800,000
British Columbia	161,800	32.3	5,180,000
Oats			
Canada	7,381,200	48.3	356,617,000
Prince Edward Island	72,800	50.0	3,645,800
Nova Scotia	23,800	44.1	1,074,800
New Brunswick	67,200	42.7	2,313,400
Québec	958,400	40.4	38,773,400
Ontario	864,400	56.4	48,699,800
Manitoba	1,488,400	46.8	69,800,000
Saskatchewan	1,868,000	47.4	90,200,000
Alberta	1,964,000	49.7	97,800,000
British Columbia	74,200	50.0	3,760,000
Rye			
Canada	880,380	19.8	17,742,600
Québec	4,320	23.5	102,000
Ontario	56,600	27.0	1,533,200
Manitoba	164,420	21.0	3,478,000
Saskatchewan	472,640	17.9	8,700,000
Alberta	178,800	21.0	3,798,000
British Columbia	3,600	36.3	131,400
Spring Wheat			
Canada	22,882,800	24.2	541,589,800
Prince Edward Island	2,840	35.0	123,400
Nova Scotia	2,980	38.6	123,400
New Brunswick	3,880	32.0	96,200

Crop and area	Acres	Yield bu/acre	Production bu.
Spring Wheat continued			
Québec	31,040	26.5	825,000
Ontario	11,260	28.0	316,000
Manitoba	2,644,000	25.8	69,100,000
Saskatchewan	15,214,000	23.5	344,800,000
Alberta	4,848,000	25.7	123,000,000
British Columbia	124,800	25.4	3,200,000
Winter wheat			
Ontario	361,800	41.1	14,860,600
Durum wheat[2]			
Canada	2,470,200	23.7	58,543,700
Manitoba	125,400	22.8	2,920,000
Saskatchewan	2,046,000	21,8	46,900,000
Alberta	298.800	26.6	8,180,000
Mixed Grains			
Canada	1,806,573	49.9	90,148,000
Prince Edward Island	59,200	50.6	2,988,000
Nova Scotia	11,760	44.7	537,200
New Brunswick	8,300	43.5	289,600
Québec	96,920	40.7	3,942,800
Ontario	845,000	59.5	50,298,600
Manitoba	217,200	40.5	8,900,000
Saskatchewan	157,200	38.2	6,160,000
Alberta	400,200	41.4	16,720,000
British Columbia	5,000	48.3	240,800

1 Data abstracted from the Statistics Canada Field Crops Reporting Series from 1968 to 1971, Catalogue 22-002, Agriculture Division, Crops Section.

2 Included with spring wheat

Note: Because of rounding of figures the sum of the Provincial totals will not balance with the Canadian totals.

in Manitoba and Alberta. Most of the rye is produced west of the Maritime provinces.

The Chemical Composition of Cereal Grains

Cereal grains vary in composition depending upon variety, environment, and soil. Both the quantity and composition of the various constituents are genetically controlled within certain limits; but within these limits the proportions are influenced by the environment. It is well known that the protein content of cereals is highest in continental climates where high temperature and low rainfall during ripening result in rapid maturation; in contrast, low temperatures and high rainfall during ripening slow maturation and lower protein content. Low protein grains are normally higher in starch content, however, since starch and protein content are inversely related. The effect of increasing soil fertility is to increase yield. Indirectly this can influence chemical composition; higher yields generally being associated with higher starch and hence lower protein content. Fertilizer can be used to increase protein content, however, usually at high rates of application.

Proximate analyses of the grains being considered are presented in Table 28. Protein is the most uniformly distributed throughout the kernel of any of the constituents. Although it is most concentrated in the germ, it is found in all kernel structures. Fat also is distributed in all kernel parts but is heavily concentrated in the germ, together with sugars and ash. The endosperm contains most of the starch.

It is difficult to measure total starch of grains[84]. Only within the last few years have methods for this determination been developed. In most chemical analyses, starch is included in the carbohydrate fraction which is generally expressed as nitrogen free extract (N-free extract). This can be defined as that component which remains when the sum of the percentages of water, ash, protein, fibre, and ether extract are substracted from 100. The N-free extract values together with their comparable starch content values (both expressed on a moisture free basis) for the grains being considered are presented in Table 29.

TABLE 28

AVERAGE COMPOSITION OF CEREAL GRAINS[1]

	Corn (Dent)	6 - row Barley	Oats	Rye	Wheat (Hard)
Moisture, %	15.0	10.6	9.8	10.5	10.0
Protein, %	8.9	12.7	12.0	12.6	13.2
Fat, %	3.9	1.9	4.6	1.7	1.9
Fibre, %	2.0	5.4	11.0	2.4	2.6
N-free extract, %	68.9	66.6	58.6	70.9	69.0
Ash, %	1.3	2.8	4.0	1.9	1.8

[1] Abstracted from Handbook of Feedstuffs, Spring Pub. Co. Inc., New York.

TABLE 29

STARCH AND N-FREE EXTRACT VALUES FOR CEREALS (dry weight basis)[1]

Cereal	N-Free Extract Total %	N-Free Extract Starch Component %
Corn (dent)	81.2	71.8
Barley (Canadian)	76.4	67.1
Oats	65.5	44.7
Rye	80.1	63.8
Common Wheat		
hard red spring	76.6	61.5
hard red winter	78.6	63.7
soft red winter	81.4	66.2
Durum Wheat	78.3	64.2

[1] Data abstracted from Miller D.F. Composition of cereal grains and forages. N.A.S. - N.R.C. Publ. 585, Washington 25, D.C. 1958

The Potential of Canadian Grown Cereals as Sources of Starch

Price, availability, and stability of supply and also the physical properties of the starch granule itself are important considerations governing the selection of any given source of starch. These factors have been considered in detail previously in this report. Probably of prime consideration, however, is the ease of separation of the starch from the other kernel constituents - protein, germ, and hull. Such separation is essential, since the successful utilization of any cereal as a source of starch

depends on the development of co-ordinated industries making full use of other fractions of the grain.

As outlined previously, processes for extracting and separating the constituents of corn and wheat are in industrial use. With barley, oats, and rye, however, little work has been done either on extraction or separation techniques or on establishing the physical or chemical characteristics of their proteins. As with other cereals, protein could probably become the most economically important constituent of these grains.

Limited information available indicates that viscoelastic proteins, similar to gluten of wheat, but in smaller amount, can be prepared from barley and rye flours[76]. Oat flour, on the other hand, only produces a clay-like protein. Limited information[18] also suggests that barley starch and protein can be expected to be difficult to separate. Hemi-cellulose-type components, originating in the hull and in the endosperm cell-walls, produce a gum-like mass when separation of starch and protein from barley flour is attempted using ordinary techniques. There is evidence to suggest that this problem may be aggravated when barley is grown under drier environmental conditions.

Barley and rye could possible compete with wheat in terms of quantity of starch available from the grain (Table 29). However, their potential usefulness as sources of starch is difficult to evaluate until extraction and separation procedures are perfected and more information is made available on the physical and chemical characteristics, and uses of allied constituents which possibly could be derived from them. A similar situation exists with oats, but this grain has the added disadvantage of being the lowest of the cereals in starch content (Table 29). Unless some specific properties of oat products could be found which give it an industrial advantage, it is doubtful if oats would compete with the other grains as a source of starch.

The Objective of Current Cereal Breeding Programs

Wheat

Traditionally, Canadian wheats have had unique characteristics

which have set them apart on world markets. These have been their high milling yield and, in the case of hard red spring wheats, good bread making quality - alone or when blended with weaker wheats; in durum, good pasta-making quality and in soft wheats, good pastry and biscuit-making quality. The tests devised by cereal chemists to assist breeders in developing these quality features have been measures of the quantity and physical features of the protein of the wheat flour, with special emphasis on gluten. Starch has only been considered in relation to dough strength and also for its possible susceptibility to damage. No determinations are made on either starch quantity or quality. Grain yield has been a high priority in breeding these wheats and has been sought by selecting for inherent yielding ability and by incorporating into varieties resistance to diseases and insects and improving agronomic features such as straw strength and early maturity. However, quality has been the dominating selection criterion, especially in hard red spring and durum programs, since it has been this feature that has maintained the marketability of these grains and without it a new variety would not be licensed.

Recently a number of breeding programs have been initiated in Canada, with both spring and winter wheats, aimed at producing varieties having greater yield potential than presently grown hard red spring types. Selection is based on yield of energy per acre with the hope that varieties developed will be able to compete in the feed grain markets. It is assumed that, since traditional quality is not a high priority, varieties produced from these programs will be somewhat weaker in dough-mixing and baking properties.

Corn

Corn provides a superior yield of energy per acre but only in areas with relatively high heat units during the growing season. This, plus the fact that other cereal grains and some annual forages produce their highest yields under cooler conditions,

places natural boundaries on the corn producing areas of Canada. Generally, as conditions become less favourable for corn they often become more favourable for alternative crops. Corn hybrids currently available should not be grown in areas with a heat accumulation of less than 2300^{o}F (based on the Ontario, or Brown's heat unit system of temperatures above 50^{o}F in daytime and 40^{o}F at night). Although breeding has increased the range of corn considerably in the past ten years, it is questionable how much further this range can be expanded because of the higher yields of cool temperature crops. Nevertheless, investigation into the response of hybrid corn to low temperature and high diurnal range forms probably the largest part of the corn improvement work in Canada.

Together with early maturity and standability, economic yields of either grain or silage have become the traditional selection criteria in most corn breeding programs. Little attention is being paid to improvement of any of the chemical components of the kernel.

Barley

Malting barley is eligible for the top barley grades - and prices. As a result, most of the emphasis in barley breeding has been directed toward the development of malting varieties. Also contributing has been the fact that for many years, the malting and brewing industries have shown great interest in barley breeding. Their advice, and information on quality parameters naturally have been used to some extent in the development and selection of new varieties.

Measurements of the enzyme systems responsible for the degradation of certain proteins, starch and the beta glucosides present in the grain are important considerations in the evaluation of barley selections for malting quality. Also of importance is the malt (wort) extract value, which is a measure of the water soluble components present in the malt, namely, fermentable sugars, oligo-saccharides, dextrins and soluble starch. These can be derived only from the starch component of the kernel.

Indirectly, therefore, high starch content is being selected for in breeding malting barleys, since a high extract value is a desired evaluation feature.

Although there is as yet no clear definition for the breeder as to what actually constitutes feeding value, considerable effort is being directed toward breeding feed barley varieties with yield of energy per acre as the main criterion of selection. It seems reasonable to hypothesize that malting and feeding qualities are not incompatible.

Resistance to diseases and insects, and improvements in agronomic features are sought in all barley breeding programs.

Oats and Rye

Improvements in energy content and in yield are the main objectives of current oat breeding programs. Energy is being increased by breeding for higher fat content combined with reduction in percentage of hull. Breeders are also concerned with the potential problems (storage stability) that could arise due to increasing the fat content. To increase yield, vigilance must be maintained against disease. Increased straw strength to prevent lodging under heavy fertilizer application also is considered a requisite to yield increase.

Higher yield and improvements in agronomic features and physical characteristics of the kernel, and increased winter hardness are the main objectives in rye breeding.

The Possibility of Improving the Starch Component of Cereals By Plant Breeding

A plant breeder can expect a reasonable degree of success in breeding a variety for any purpose if he is provided with a reasonable set of specifications. However, he should not be placed in the position of having to decide what the consumer requires. If possible, the needs of the consumer should be made known to the breeder ten to twelve years in advance, since the development of a variety is a very lengthy process. It also is necessary for the breeder to have available a sufficient

range of genetic variability for the desired characteristic to warrant a crossing and selection program. Techniques for testing and selecting the desired characteristic also must be available. These should be simple, inexpensive, and require only a few grams of seed, since only small quantities of seed of breeders lines are available for testing early in a breeding program. In addition, the desired characteristics must not be associated genetically with undesirable features of a variety.

As indicated previously, both the quantity and composition of the various constituents of cereal grains are under genetic control. The proportions also are held fairly constant relative to one another. A quantitative change in any one of them must result in a corresponding increase or decrease in one or more of the remainder. Since total utilization of all components would be necessary for an industry to operate efficiently, a decision as to adjustments to be made would depend upon the relative, long term economic position of the various components.

Wheat

The marketing of Canadian wheats has demanded that the quality of new varieties remain fairly constant. Therefore, the range of genetic variability for starch quantity has remained relatively narrow. A difference of only 5% was obtained for the starch content values from samples of nine grades of hard red spring wheat obtained from five locations in western Canada over a period of four years[77]. The mean value was 52.5% (non-dried weight basis). It would be difficult to select for starch content much beyond this range from populations derived from crosses between the wheats of this class currently being marketed.

Johnson and Fellers[78], using a modification of the Fesca process for protein-starch separation were able to extract 67 lbs. of starch and 6.5 lbs. of protein from 100 lbs. of soft wheat and 54.0 and 11.8 lbs., respectively, from hard wheat. Obviously, soft wheat yields more starch and this characteristic presumably would be heritable. Soft wheats are being used in a number of the winter and spring "feed" wheat breeding programs currently underway in Canada. It is probably here where selection for

increase in starch content could be concentrated. However, as shown by the above figures, protein content could be expected to decrease as starch increased. This would not necessarily mean a reduction in gluten content, however. Gluten is a colloidal complex formed from the wheat endosperm proteins, gliadin and glutenin. There is some evidence[85] that this fraction is genetically independent of other protein fractions and of total protein. Theoretically, it may be possible to maintain or even increase gluten content while still selecting for starch increase.

Specialty starches - those with a high proportion of amylose or amylopectin - currently are being derived from corn. The ratio of amylose to amylopectin in cereals is genetically controlled, generally by a single gene which has mutated. Although genes controlling the amylose and amylopectin ratio have not been located to date in wheat, they probably do exist in some variety currently not being cultivated. If not, they could probably be inducted by a mutagenic agent. Once obtained, it would be a relatively simple task to utilize them in breeding for specialty starches in wheat as has been accomplished in corn.

Corn

Corn is a basic food plant that is high in carbohydrate, low in quality and quantity of protein and relatively low in oil. It has been well established that all of the components of the kernel are under genetic control and that both quantitative and qualitative changes can be produced through breeding[79].

Numerous genes have been described which affect corn quality. The waxy mutant (wx) which is responsible for a high proportion of amylopectin starch was first described in 1909. Since that time, mutant genes producing high amylose and high reducing sugar content have been discovered and utilized singly or in combinations. Genetic diversity for both oil quantity and quality exists in corn. Hybrids with increases of from 50-75% oil have been selected and data are available which

suggest that hybrids with a combination of 8% oil containing up to 70% linoleic acid (unsaturated fatty acid) are attainable. Commercial acreages of corn containing 8% oil were grown in Illinois in 1971. However, the quality of the oil has not been indicated[86]. Corn also has a wide range of genetic variability for protein quantity, although the high protein hybrids that have been developed have never become commercially important because of the inferiority of their protein and their low yields. Lysine and tryptophan are deficient in corn protein but considerable progress has been made breeding for increase in these amino acids following the discovery of the opaque-2 gene in 1963[80].

Most of the hybrids currently being grown which possess gene mutations are lower in yield than standard market corn - either in total grain yield or in the yield of the modified component. They are used, therefore, as specialized hybrids; the yield reduction being compensated for by the economic advantage brought about by the specialty feature. There is some evidence, however[87], that improvements in oil quantity and in protein quality can be incorporated without loss of yield. If this could be accomplished, hybrids of this type could become the standard market corn. Increase in energy and nutritional value from higher oil content and amino acid balance would benefit the feed industry. These features also would be important for the industrial processor, since oil and protein are his most valuable products in terms of cents per pound.

As far as the starch component is concerned, it must be assumed that increases in quantity of oil and/or protein would result in a concomitant reduction in quantity of starch. Economic priorities, once again, would play the decisive role in determining the chemical content of the eventual improved product.

Corns which are high in amylose and amylopectin are opening up new development areas. Approximately ½ million bushels of high amylopectin corn are being used annually in Canada. This is being produced from American developed hybrids. Because of their specialty features and attendant low yields, these corns

are approximately 50% more costly than ordinary market corn. If breeding could reduce the cost of specialty corns, more uses for them probably would be identified.

Barley, Oats, and Rye

The chemical components of the remaining cereals obviously are under genetic control. However, only in the case of barley is there sufficient information to evaluate the potential of this grain as a source of starch.

If it is accepted that malt extract yield is an indication of starch content, it can be assumed that considerable genetic variability exists for this component, since malt extract values vary considerably in barley. The gene in barley which increases the proportion of the amylose component (at the expense of amylopectin) has already been referred to. This gene currently is being used in a number of Canadian breeding programs in an attempt to develop barleys with special properties.

Presumably, if extraction and separation techniques could be developed, barley could become a source of starch amenable to improvements in both quantity and quality. The amino acid balance of this grain is satisfactory, relative to that of corn; although some nutritionists suggest it could be improved, especially for the use of non-ruminant animals. These improvements could be incorporated concurrent with improvements in starch.

The potential of hulless barley as a source of starch should be evaluated. This type of barley presumably contains a greater percentage of starch than hulled barley[85]. It also should contain considerably less hemicellulose than the hulled type, since most of the hemicellulose is located in the hull. Freedom from hemicellulose should permit separation of starch from protein, since it presumably is this component which causes the gum-like mass produced during attempted extraction. Breeding hulless varieties would be a relatively simple task, since the hulless condition is controlled by a single gene.

MISCELLANEOUS CROPS

Potatoes

Potatoes occupy approximately 300 thousand acres in Canada; one third of which is in the Maritime provinces, one third in Québec and Ontario and the remainder on the prairies and British Columbia. Average yields of near 165 cwt. per acre give a total annual production of approximately 50 million cwt.

Approximately 18% (13 - 21) of the potato is starch. Although potato varieties currently being grown in Canada have been developed primarily for use as table potatoes, very high starch yields can be obtained from them if they are grown where moisture is not a limiting factor and proper management is practiced. Should breeding emphasis dictate, varieties with higher starch content could be developed. European varieties with starch content in excess of 23% are available and Canadian bred seedlings with starch content in the range of 21% currently are being tested[88]. There are indications of a negative correlation between high starch content and high yield[88] and this would have to be overcome before high yielding and high starch producing varieties could be expected.

Field Peas

For the past few years, approximately 80,000 acres have been annually devoted to field peas in Canada. Most of this acreage is in Manitoba with some in Alberta and lesser amounts in Quebec, Ontario, Saskatchewan, and British Columbia. Total production is generally around 1.75 million bushels with Manitoba producing slightly over 1 million.

The current major use for this crop is for canning purposes or for bulk processing for use as pea soup. Because of its high protein content (25.8%), however, there currently is considerable interest in using field peas as a supplement to cereals in animal feeds. It is an excellent source of lysine and appears to be adequate in all other essential amino acids except methionine.

The starch component of field peas constitutes 55-58% of the total solids and is readily separable from the protein.

Both wet milling and air classification separation techniques have been developed[81]. With the wet milling technique, yields of 36% protein concentrate and 64% starch fraction (at 10% moisture) have been obtained.

Pea starch has been tested as an adjunct in the brewing and distilling industries. Compared to potato starch, it cooks better and gives higher alcohol yields and does not contribute to the flavour of the distillate. Another potential use being evaluated is as a desliming agent in potash refining where it could replace either potato or corn starch.

Effort is being directed toward breeding for yield increase in field peas with some consideration being given to increasing protein content. No work is being done on either starch quantity or quality.

Horse Beans

Horse beans are a small seeded relative of the garden broad bean. In tests conducted in Manitoba[89], yields of 100 bushels per acre have been obtained compared to 60 bushels per acre for hard wheat. The chemical composition and amino acid balance is similar to that of field peas. This crop has an advantage over field peas in that it stands upright in the field and can be harvested with standard harvesting equipment. Because of its high protein (from 24 to 33%) this crop is being evaluated as a potential protein source as a supplement to cereals. No evaluation is being made of its starch.

Triticale

Triticale is a man-made grass species resulting from an inter-specific cross between rye and wheat. Although early work suggested high yielding potential, triticale has shown no advantage over other cereal crops. It yields approximately the same as hard wheat but is not a bread-making crop. Compared with other cereal grains (Table 28), its composition is as follows: crude protein 17.1%, crude fat 1.7%, crude fibre 3.1%, ash 2.1%, and N.F.E. 76.0%.

If triticale becomes a crop of commerce, initially its use

will be as a feed grain. Although it does not produce as much energy per acre as crops such as barley, it is an efficient feed in that less is required by the animal to put on a pound of gain. However, a palitability problem exists with triticale which has been traced to its susceptibility to ergot.

Triticale has been tested in the distilling and brewing industries and results appear promising. Breakfast foods and pancake flour from triticale also have been tested and have been rated satisfactory[90].

Current plant breeding effort is being directed toward improving agronomic performance and kernel characteristics.

Jerusalem Artichoke

The tuber of the Jerusalem artichoke contains no starch but up to 73% inulin (on a dry weight basis). Inulin is a polysaccharide composed of chemically linked fructose units. This crop has wide adaptability although it must have winter cover under more severe conditions in order to prevent killing of the tubers. Currently there is no acreage of this crop in Canada. Under test at Morden, Manitoba, in 1971, artichoke yielded 684 cwt. per acre compared to 424 cwt. for Kennebec potatoes and 290 cwt. for Norchip potatoes. No current effort is being made to improve this crop in Canada.

SECTION IX: SUMMARY

SUMMARY

CANADIAN STARCH INDUSTRY

The starch industry in Canada, whose origin antedates Confederation, is presently comprised of six companies; three of which manufacture starch from corn, one from wheat, and two from potato. Corn starch production, which represents about 80% of the total, is concentrated in south eastern Ontario. Wheat starch is produced at Thunder Bay, and potato starch is manufactured at Grand Falls, N.B., and Vauxhall, Alberta.

Although the production processes are characterized by marked differences, they share the common objective of separating starch from the other raw material components. The starch thus obtained may be a) sold in its natural form, known as unmodified starch, b) modified to starches of different characteristics, or c) converted into other products including glucose (corn syrup), dextrose (corn sugar), or dextrine. All of these products possess characteristics which make them suitable for particular applications. In total, several hundred grades of starch or starch-derived products are produced by the industry.

By-products of starch production are also significant. Probably the most important relative to the value of starch obtained is vital wheat gluten, a protein product used in many countries to fortify flour used in bread making. It could be considered a co-product of wheat starch as the value of gluten obtained from a bushel of wheat approximates the value of starch. By-products of corn starch production include corn oil, and gluten feed and meal. The first is used as a salad and cooking oil and in margarine; the two latter products are used in animal and poultry feeds. The by-product of potato starch is used as a fertilizer or feed but the value is relatively low.

The following table summarizes the total demand and supply of starch and starch-derived products. It shows con-

sumption to have increased from 268 to 479 million pounds between 1957/59 and 1969. In terms of raw material, 1969 consumption is equivalent to 12 million bushels of corn, or 18 million bushels of wheat or 43 million hundredweight of potatoes.

TABLE 30

ESTIMATED PRODUCTION, TRADE & CONSUMPTION OF STARCH & STARCH-DERIVED PRODUCTS

(Million pounds)

	Average 1957/59	1966	1967	1968	1969
Consumption	268.3	411.8	422.5	452.2	479.0
Trade:					
Imports	34.7	72.0	75.2	73.8	86.9
Exports	-	-	-	-	-
Production	233.6	339.8	347.3	378.4	392.1

Imported products are principally comprised of more sophisticated grades of starch which cannot be produced economically in Canada, and low cost unmodified starch at prices generally below the prevailing prices of Canadian-produced starch.

Analysis of the consumption pattern shows starch to account for almost half of the total. Glucose represents about 30% and the balance is comprised of dextrose, dextrine and other products which includes consumer products such as laundry starch, edible corn starch and corn syrup. Among the more important starch markets are the paper industry (50% in 1969) and corrugating industry (12%). The confectionery industry accounts for 40% of glucose consumption. Second in importance is ice cream which represents 18% of the total glucose usage. Prices of starch and glucose range upward from base prices of approximately $7.00 and $8.00 per hundred pounds respectively.

INTERNATIONAL SITUATION

Annual world production of starch and starch derived products is estimated at 22,900 million pounds. The major commercial sources of starch are corn, potatoes, cassava root, and wheat. Industrialized countries produce and consume most of the world's starch products. The United States starch industry is based on corn and produces over 8,000 million pounds of starch and starch derived products annually. Other large producers (with the major raw materials used) include Japan (corn and potatoes), the EEC (corn and potatoes), Canada (corn), Australia (wheat) and Thailand (cassava root). World trade in starch is estimated at 7.5 per cent of world production. The United Kingdom is the major importer of starch products. The Netherlands exports large quantities of potato starch and corn starch. Thailand is an important exporter of tapioca starch to Japan and North America. High tariffs in most countries combined with the low price of most starches restrict export opportunities. The wide availability of starchy raw materials in most countries has led most governments to encourage the development of a domestic starch processing industry.

The section dealing with the international situation includes a review of the starch industries in selected countries which are of particular interest to Canada.

RESEARCH AND DEVELOPMENT

Sources of starch and production methods

There are many alternatives to corn as a source of starch. Some, such as wheat, potato and cassava may, under special local circumstances, be the preferred source. Of paramount importance always is the successful marketing of the other crop constituents, or "co-products". Thus the wheat starch industry succeeds to the extent it can sell the gluten. The potato starch industry, in contrast, suffers in that no

valuable by-products are obtained. Factors that could result in commercial success for new sources of starch such as peas, oats, barley etc. are (a) a demand for high amylose or other specialty starch provided by that crop; (b) a demand for a new co-product such as vegetable protein for human foodstuffs and animal feed. Thus, research into new starch sources must concentrate on these factors, in particular the concept of total crop utilization.

Direct conversion of starch in flours or intact grains to glucose syrups with improved utilization of the remaining protein could well become feasible in the near future. This could alter the preferred source of starch for syrup production. Once again, enzyme research is the key to the problem.

Recovery of starch from Canada's total annual production of cereal crops (wheat, barley, oats, rye) would total almost 40,000 million pounds. This should be viewed as a valuable renewable resource with as yet unrealized potential. The present Canadian production of starch and starch derived products consumes less than 2% of the total wheat and corn starch grown.

Glucose and other sweeteners

In the past decade the use of enzymes to produce syrups from starch has become prominent. The whole field of enzyme technology is likely to assume great importance in many industries. Research concerning enzyme production, enzyme modification and enzyme utilization, and fundamental studies concerning the action of enzymes (particularly starch degrading enzymes) could result in long term benefits to the starch industry.

The production of fructose from glucose has been the subject of much research elsewhere. The major recent development has been, once again, in the field of enzyme technology. Commercial processes are now in operation in the United States and Japan using glucose isomerase enzymes for production of fructose-containing glucose syrups. Further research will

probably improve the conversion processes but Canada is probably too far behind now to effectively enter this research field. Alternative sources and methods of production of fructose, and its utilization and possible medical benefits (or harmful effects) are worthwhile subjects for study.

The compound maltitol, obtained by reduction of maltose, has considerable potential as a dietetic sweetener. Its reported high sweetness and almost zero utilization by the body make it potentially the most valuable "semi-synthetic" sweetener yet to appear on the market. Although there is no public interest being shown by industry, the possible social benefits of this product suggest that research into its production and physiological and pharmacological effects would be worthwhile. Enzyme research has been the key to development of processes for production of the sweetener known as maltitol. This product could have social benefits as a sweetener for diabetics and the obese.

Novel Utilization of Starch and Starch Derived Products

Potentially the most extensive new markets for starch are likely to be found in the chemical industry. Alcohol production has been the subject of a previous report[75]. The use of starch and its derivatives in rubbers and other polymers such as urethane foams, alkyd resins, graft copolymers etc., may be a major future market. However, products developed to date have not achieved commercial success. Future success of these or related products is therefore largely a matter for speculation, whereas a simple well-defined product such as fructose has properties and potential market which are easily identified. Nevertheless, it is felt that technical advances combined with decreasing petrochemical availability should in the long term favour starch utilization in the chemical industry.

FUTURE PROSPECTS

Growth in the industry is expected to continue at the

rate experienced during the past decade. On this basis, total volume in present markets should be close to 800 million pounds in 1978. In addition, 200 million pounds of fructose, a newly developed product, and 100 million pounds of dextrose could be made if an economic price relationship with sugar could be established. On this basis, demand in 1978 could be equivalent to 101 million cwt. of potatoes, 28 million bushels of corn or 42 million bushels of wheat. These volumes would be more than twice the 1969 requirements.

PLANT BREEDING

Total utilization of all of the constituents of grains and the other components of field crops used for industrial processing is essential in order for an industry to function efficiently. Decisions as to which of the constituents to adjust by plant breeding, and the degree of adjustment, must depend upon the long term economic potential of the various constituents.

The ease of separation of the starch from other plant or grain constituents is an important consideration governing the selection of any source of starch. For wheat, corn and potatoes starch extraction and separation techniques are in industrial use. For other crops such as barley, oats and rye these techniques have not been developed; nor is information available on the physical or chemical characteristics or uses of allied constituents that could possibly be derived from these crops. Their potential usefulness as sources of starch, therefore, has been difficult to assess.

Research philosophy in the development of cereal crops in Canada has been traditionally aimed at the production of wheats high in milling and baking quality, and barleys of good malting quality. The development of these specialty features requires no direct determinations of either starch quantity or quality. Similarly with potatoes, which have been primarily developed for table use, little consideration has been given to starch content. With corn, not only has starch

content been ignored, little attention has been paid to improvements in any of the other chemical components of the kernel.

Possibilities exist for improving both the quality and quantity of starch in Canadian field crops and are summarized as follows:

a) The range of genetic variability for starch increase from populations where hard wheats have been used as parents in crosses can be expected to be small. Soft wheats, since they yield more starch, offer greater potential in breeding work. There is evidence that gluten content in wheat is genetically independent of other protein fractions and of total protein. Theoretically, therefore, it may be possible to maintain or even increase gluten content while still selecting for starch increase.

b) Increase in quantity of starch in corn would result in a concomitant reduction in quantity of oil and/or protein. Improvements in quality of both oil and protein are now possible without loss of yield. Unfortunately, specialty corns, those high in either amylose or amylopectin starch would be expected to be low in yield.

c) Presumably, if extraction and separation techniques could be developed, barley could become a source of starch amenable to improvements in quantity and quality. The potential of hulless barley as a source of starch should be evaluated.

d) The development of potato varieties higher in starch than those currently being grown is possible using germplasm currently available.

SECTION X: CONCLUSIONS & RECOMMENDATIONS

CONCLUSIONS & RECOMMENDATIONS

From the foregoing analysis, the Committee concludes that favourable prospects exist for the future growth in Canadian consumption of starch or starch derived products. Total sales volume in 1978 is expected to be 78% greater than in 1968. Given a situation favourable to the greater use of dextrose and fructose-bearing syrups produced from starch, they believe that 1978 volume could be twice the 1968 level.

The Committee also concludes that the Government could assist the Canadian starch industry to achieve its maximum potential by creating an environment favourable to the development of domestic production. Specifically, they regard the present import level to be too high relative to other developed countries, and that measures should be taken to reduce, or at least maintain, the present volume. In this respect they note that there would be an additional annual domestic requirement for 2½ million bushels of corn or 3½ million bushels of wheat if imports could be entirely displaced by domestic production. The Committee also holds the view that conditions for obtaining an increase in exports are not favourable because of low priced raw materials and export subsidies which are available to foreign starch manufacturers. They recognize, however, that the potential for certain specialty lines may be sufficient to warrant an augmented market development activity in selected areas.

Concerning raw materials, it is the Committee's conclusion that some grains not presently used for starch manufacture may be able to compete with present products. Utilization of these crops, however, is contingent upon the development of commercial processes which would enable production from these materials to compete with present source products. Development of special strains of grain used in the starch manufacture are regarded as being potentially advantageous, provided due consideration is given to the possible effects that this development would have upon the total return obtainable from the raw

material. At the least, the total monetary yield should not be less than presently realized, and wherever possible, it should be greater. However, the possibility of incremental benefits should be taken into consideration when assessing the attractiveness of utilizing an alternate crop.

Finally it became apparent during the course of the study that the Canadian starch industry had a general awareness of foreign technological and other developments which could have an important impact on the industry in the future, but neither the industry or the Government were fully cognizant of all aspects. This is most notable in respect to developments of starch-based sweeteners where significant advances have been made recently in both Europe and Asia. To a lesser extent, knowledge of situations and conditions which enable foreign products to compete in the Canadian market is also lacking.

RECOMMENDATIONS

The Committee respectfully submits the following recommendations which are designed to ameliorate the problems noted in the foregoing analysis. Although some will have a bearing upon more than one area of activity, they have been grouped by area of greatest impact.

Technological, Research & Development

1 A government research centre be designated to study the total utilization of the components of field crops with a view to maximizing the economic return. Starch research should receive high priority in this program. As envisaged, this centre would have responsibility for:

a) establishing effective liaison between all industries associated with raw materials derived from field crops and those responsible for the development of these raw materials, i.e. the plant breeder,

b) maintenance of a watching brief on techno-logical and market developments in Canada and foreign countries in an attempt to establish a marketing advantage for Canadian field crops and products.

c) developing technology and obtaining needed information required in respect to the specific properties and utilization of the constituents of various field crops.

Information gleaned from this activity could be used by plant breeders to develop specialty features which could lead to improving the marketability of field crops or to new industrialized products derived from them. The work of this centre could include research to develop a) a commercial starch process for barley (discussed on p. 69), b) high amylose crops (p.70), and c) modified by-products or new products from waste (p.69).

The centre could also act as an advisor on scientific matters pertaining to industries deriving raw materials from field crops.

2 Encourage University Research. This could be done under contract with Industry or Government.

Incentives to Canadian Production

3 Measures that would have the effect of eliminating or reducing the ability of foreign starch products to compete in Canadian markets should be examined and implemented where possible. It is suggested that the objective could be achieved by one or more of the following:

a) A tariff increase on starch, starch-derived products, and corn grits.

b) Quotas limiting the quantity of imports of these products.

c) Effective action to prevent the dumping of subsidized exports into Canada.

d) Removal of the tariff on corn.

Although it is conceded that prospects for increases in tariffs on starch products are unlikely in the present international trading environment, an increase would be an effective means of making Canadian starch products more competitive. At the present time, all imported starches carry a duty of $1.00/100 lbs. (M.F.N.). A higher tariff rate would raise the price of low-priced starches to a more competitive level and encourage the use of Canadian starches. As an alternative the application of an ad valorem duty to treated starches such as modified starches and dextrines would encourage the manufacture of more specialty grades in Canada, but would not have as great an impact on production because of their relatively low volume.

A quota on starch products could be another method of restricting the volume of starch imports. Elsewhere in the study it has been noted that imports are accounting for an increasing proportion of total consumption. If it should not be possible to modify this trend through tariff increases, perhaps an annual quota could be introduced which would hold the volume at a pre-determined level. Once this level was reached, all additional starch requirements could be supplied by domestic production.

In respect to "c", an investigation into alleged dumping of potato starch is presently being conducted. Unfortunately, a large quantity of starch is believed to have been already dumped, and the statutes do not provide for retroactive dumping duties. It is therefore desirable to identify dumping at the earliest possible moment and it is

suggested that Customs and others concerned with fair trade practices, should be alerted to watch for imports of this type.

Concerning the proposed removal of the tariff on corn, it is the Committee's belief that this would tend to lower Canadian corn prices which are the basis of all industrial starch prices. A move of this type would be in keeping with the general trend to lower tariffs, but objections to such a move could be anticipated from Canadian corn producers.

Market Development

4 Consideration be given to creating an environment conducive to the greater utilization of starch-based sweeteners.

In order to achieve this objective sucrose prices should be relatively stable at a level that would permit the production and sale of other sweeteners at competitive prices on a dry basis.

The International Sugar Agreement has tended to increase world sugar prices, and it would appear that the lower end of the price range for this product will likely remain above 10¢ per pound, wholesale Montreal, at least until the expiry of the present contract on December 31, 1973. Prior to the agreement, prices were as low as 6¢. Assuming that the I.S.A. is renegotiated, it seems unlikely it would include provision for lower prices. Therefore this aspect of the problem may be resolved if the indicated level is attractive for sweeteners. However, it must also be noted that the recent Tariff Board Report on sugar recommends "reductions in the (tariff) rates for raw sugars

to lower the costs of Canadian production and the prices to the Canadian consumer". If implemented, these reductions could counter the expected trend to higher sugar prices under the I.S.A., and render the prospects for glucose and dextrose less favourable.

In respect to price stability, the International Sugar Agreement does not guarantee a specific price range although producing countries are required to adjust quotas in response to price movements. The desirability of a relatively stable price has been recognized by Japan which maintains domestic prices through a series of levies and subsidies which tend to balance over a period of time. It is suggested that a similar program in Canada would be useful to industrial users, and would establish a favourable climate which would encourage investment in production facilities for starch-based sweeteners.

5 Food and Drug regulations be amended to permit use of starch-derived sweeteners on the same basis as sugar in the manufacture of food products.

The present regulations carry limits on the amount of glucose and other non-sucrose sweeteners which may be used. These regulations reflect "good manufacturing practice" in the past. However, technological developments have led to an additional use of glucose, and the regulations now impose a limit on the amount which can be used and in some cases forbid its use. The Committee believes that regulations should be modified to permit the use of glucose and other starch-based sweeteners on the same basis as sucrose, the only restriction being the product characteristics desired by the manufacturer.

6 Export potentials of all products produced by the industry be assessed with a view to identifying and exploiting opportunities for Canadian products in foreign countries.

General

7 Encouragement be given to the establishment of a starch industry association. In addition to being a forum for discussion of mutual problems, the association could serve as a point of contact between Industry and Government.

SECTION XI: GLOSSARY

GLOSSARY

Canadian industry does not use the accepted Codex Alimentarius term for a "concentrated aqueous solution of nutritive saccharides obtained from starch" -- namely, glucose syrup. Instead, the term "glucose" is used. Under Internationally agreed rules of nomenclature in Organic Chemistry, glucose is a specific and well defined chemcial, not the mixture of components found in starch hydrolysates.

A further difficulty is found in the use of the word, sugar, to mean both sucrose (table sugar), a well defined chemical compound, and also to mean the class of compounds, the carbohydrates or saccharides, which includes glucose, fructose, maltose, etc.

For the purpose of this report the Codex Alimentarius definition of glucose syrup will be used, and will not be interchanged with glucose. Similarly, when table sugar (refined cane sugar or beet sugar) is being referred to, the word sucrose will be used. "Sugar(s)" will be used to describe a variety of carbohydrates, such as glucose, sucrose, fructose, maltose.

Amylopectin:	A component of starch, it is a branched chain polysaccharide composed of chemically linked glucose units.
Amylose:	A component of starch, it is a straight chain polysaccharide composed of chemically linked glucose units.
Baume:	A hydrometer scale commonly used to measure the density of viscous solutions.
Degree of Polymerisation (D.P.)	The number of structural units contained in a polymer. Thus, for amylose and amylopectin, the D.P. is the number of glucose molecules linked together to form the polysaccharide chain.
Degree of Substitution (D.S.)	The average number of substituents per glucose unit in a substituted starch.
Dextrose:	Crystalline D-glucose. Dextrose monohydrate contains water of crystallisation. Anhydrous dextrose contains no water of crystallisation.
Dextrose Equivalent: (D.E.)	A measure of reducing-sugar content calculated as anhydrous dextrose and expressed as a percentage of the total dry substance.
D-Fructose:	Also known as levulose, and commonly just fructose. An important naturally occurring monosaccharide.
Fructose-containing glucose syrup:	Glucose syrup in which part of the glucose has been converted to fructose.
D-Glucose:	The central monosaccharide in nature. Commonly, just glucose. May exist in different forms known as the alpha and beta-anomers D-glucopyranose and D-glucofuranose.
Glucose Syrup:	A purified concentrated aqueous solution of nutritive saccharides obtained from starch. Normally contains some glucose, maltose, and other oligosaccharides of glucose. Also known in Canada as "Glucose", and in the U.S.A. as Corn Syrup or Corn Syrup Unmixed (C.S.U.).
Hydrolyse:	To break the linkage between saccharide units by reaction with water and catalyst.

Invert Sugar:	A mixture of equal amounts of D-fructose and D-glucose obtained by hydrolysis of sucrose. Commercially, may also contain sucrose.
Isomers:	Compounds possessing identical molecular formulae but differing in the nature of sequence of bonding of their atoms, e.g. D-fructose and D-glucose are isomers. The symbols L and D are used as prefixes to distinguish between certain types of isomers.
Isomerase:	A enzyme which converts one isomer into another.
Maltose:	A reducing disaccharide composed of two chemically combined glucose units. May be obtained by hydrolysis of starch.
Monosaccharide:	A class of carbohydrates to which fructose and glucose belong.
Oligosaccharides:	Compounds containing up to (arbitrarily) ten chemically linked monosaccharide units. Maltose, therefore, is an oligosaccharide containing two such units. When more than ten monosaccharide units are present the compound is generally referred to as a polysaccharide.
Polysaccharide:	See oligosaccharide.
Reducing (as in reducing sugar):	Descriptive of a chemical property possessed by certain carbohydrates.
Starch:	A naturally occurring mixture of amylose and amylopectin.
Sucrose:	A naturally occurring, highly crystalline, non-reducing disaccharide composed of chemically linked D-glucose and D-fructose units. Also known as cane sugar, beet sugar, sugar, white sugar, table sugar, household sugar.
Xylose:	A monosaccharide which occurs naturally in chemical combination with itself and other sugars.
Xylan:	A naturally occurring polysaccharide composed of xylose and other sugar units.

SECTION XII: APPENDICES

APPENDIX A

A-1

QUANTITY & VALUE OF
CANADIAN IMPORTS OF STARCH & STARCH-DERIVED PRODUCTS
(Millions-Except Unit Values)

			1957/9	1966	1967	1968	1969	1970	1971
A. Starch	Total	Pounds	18.0	44.5	49.0	47.5	54.0	53.0	47.1
		Value	1.7	4.0	4.2	4.0	4.1	3.3	4.0
		$/cwt.							
	Corn	Pounds	12.8	19.4	18.4	20.0	21.8	9.2	8.5 (1)
		Value	1.3	2.4	2.4	2.3	2.3	1.1	n.a.
		$/cwt.	10.19	12.59	13.01	11.37	10.51	12.10	n.a.
	U.S.	Pounds	12.1	16.6	16.1	17.2	20.4	8.7	8.0 (1)
		Value	1.2	2.3	2.2	2.1	2.2	1.1	n.a.
		$/cwt.	10.27	13.66	13.92	12.35	10.91	12.38	n.a.
	Potato	Pounds	2.1	9.5	6.9	7.7	13.7	19.8	23.4 (1)
		Value	.2	.7	.6	.7	.9	1.1	n.a.
		$/cwt.	8.23	7.56	8.88	8.64	6.42	5.67	n.a.
	U.S.	Pounds	1.7	2.0	3.2	5.2	7.7	3.8	4.0 (1)
		Value	.2	.2	.4	.5	.6	.4	n.a.
		$/cwt.	9.05	11.34	11.33	8.82	8.37	10.49	n.a.
	Neth.	Pounds	.1	7.2	2.4	2.3	5.8	16.0	19.2 (1)
		Value	+	.5	.2	.2	.2	.7	1.0
		$/cwt.	6.60	6.57	8.19	8.43	3.80	4.45	5.17
	Tapioca	Pounds	1.6	12.7	20.1	15.8	14.6	20.1	9.8 (1)
		Value	.2	.7	1.1	.9	.8	1.0	.6
		$/cwt.	13.20	5.49	5.40	5.90	5.67	4.78	6.60
	Braz.	Pounds	.1	6.8	6.2	4.4	6.3	7.8	1.1
		Value	+	.2	.2	.1	.2	.2	+
		$/cwt.	10.68	3.65	3.10	3.38	2.59	2.96	3.46
	Thai.	Pounds	n.a.	1.3	8.6	7.4	2.2	5.6	4.4
		Value	n.a.	.1	.4	.3	.1	.2	.2
		$/cwt.	n.a.	4.78	4.49	4.35	3.98	3.40	3.78
	Rice	Pounds	1.5	.9	.7	1.0	1.0	.8	1.0
		Value	.4	.1	.1	.1	.1	.1	.1
		$/cwt.	9.37	10.23	12.77	11.78	12.26	12.89	12.15
B. Glucose & Dextrose (2)	Total	Pounds	12.2	18.0	19.1	20.9	27.9	21.0	23.2
		Value	1.0	1.6	1.7	1.8	2.2	1.8	2.0
		$/cwt.	8.19	8.88	8.90	8.61	7.88	8.57	8.62
	U.S.	Pounds	11.7	17.2	18.4	20.1	27.6	20.3	22.7
		Value	.9	1.5	1.6	1.8	2.2	1.7	2.0
		$/cwt.	8.00	8.72	8.94	8.90	8.04	8.62	8.77
C. Dextrine & Dextrine Prep.	Total	Pounds	4.5	9.5	7.1	5.4	5.0	4.4	4.4
		Value	.3	.8	.6	.5	.5	.4	.5
		$/cwt.	6.66	8.42	8.45	9.25	10.00	10.00	11.36
	U.S.	Pounds	1.3	2.3	2.4	2.4	2.2	1.6	1.2
		Value	.1	.3	.2	.2	.2	.2	.2
		$/cwt.	9.39	10.94	10.19	9.98	11.20	12.57	14.56
	Neth.	Pounds	2.0	4.6	4.5	2.5	2.2	2.0	1.9
		Value	.1	.3	.3	.2	.2	.2	.2
		$/cwt.	6.90	6.70	7.19	8.13	7.90	8.21	9.58
D. ALL PRODUCTS	Total	Pounds	34.7	72.0	75.2	73.8	86.9	78.4	74.7
		Value	3.0	4.7	6.5	6.3	6.8	5.5	6.5

Source: Developed from Statistics Canada; Imports by Commodities

\+ Less than .05

(1) Starch import statistics were changed in 1971 by addition of Class No. 429-74-Industrial starches. Category includes starches of all botanical origins, and total amount was 29.0 million pounds.

(2) Official classification includes fructose but "fructose" was omitted from the heading because imports are believed negligible.

APPENDIX B

Starch Policy in the Netherlands and E.E.C.

The starch industry in the Netherlands must be studied in the context of the total E.C.C. starch industry.[1] The common External Tariff and the Common Agriculture Policy of the E.E.C. greatly influences the production of starch in the Netherlands. Approximately one-third of total starch production in the Common Market is from potatoes - chiefly Netherlands and West Germany - and almost two -thirds is corn starch. Other starches, chiefly wheat and rice, supply the balance of starch requirements. The bulk of E.E.C. starch production is in the hands of four concerns:

1. CPC International controls about 80 per cent of all corn starch production in the Common Market.
2. A.V.E.B.E., the Dutch Co-op, accounts for over 80 per cent of the Dutch production of potato starch and for more than 66 per cent of the production in the countries of the E.E.C. It is the largest producer of potato starch in the world.
3. The Scholten-Honig concern, also Dutch, manufacturers of corn, potato, wheat, and rice starch.
4. Roquette, France.

In 1966, the E.E.C. in Brussels formulated a policy whereby the basic principle was laid down that "Starch is starch", irrespective of the raw material. Because of its predominance corn starch was used as the basis for implementation of the Common Market starch policy. A fixed price was established for corn to be used by starch producers. This price, was set at 6.8 units of account per 100 kilos, equals Fls. 24.62 and was still applicable at the time of writing.[2]

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[1] Based on inter-office correspondence from F.W. Zechner, Commercial Officer, The Hague, Netherlands to Agriculture, Fisheries, and Food Products Branch, I T & C, Ottawa.

[2] The unit of account (UA) is used by the E.E.C. as the common denominator for all the currencies of member countries. It is equal to the approximate value of the U.S. dollar, or Fls. 3.62. Devaluation of the U.S. dollar may necessiate some changes in the various exchange ratios.

Corn starch producers receive a production restitution which might better be called a subsidy except that the matter is complicated by the E.E.C. variable levy system and the E.E.C. fixed price for corn. Little E.E.C. corn is used by the starch industry and producers import corn at the E.E.C. threshold price for corn (e.g. world price plus the levy). Producers receive a restitution equal to the difference of the threshold price and the E.E.C. fixed price for corn. The following will illustrate this:

E.E.C. threshold price for corn in the month of February, 1972	Fls. 35.69 per 100 kilos
World corn price, February 23, 1972	Fls. 20.20 per 100 kilos
Levy	Fls. 15.49 per 100 kilos
E.E.C. threshold price for corn	Fls. 35.69 per 100 kilos
E.E.C. fixed price for corn	Fls. 24.62 per 100 kilos
Production restitution	Fls. 11.07 per 100 kilos

The threshold price for corn and other grains, established each year, starts to become operative on August 1. It is increased slightly each month as of October 1 up to and including May to offset costs of storage for E.E.C. produced grains. Consequently, the production restitution goes up slightly for 8 consecutive months starting October 1 of each crop year.

Exporters of corn starch in the E.E.C. receive rebates (restitutions) to make up for the difference between the world market price and the fixed price of corn. In the past few years, world corn prices have moved below the fixed price of Fls. 24.62 per 100 kilos, except during the relatively short "corn blight panic" some time ago. Should the world price become equal to the fixed price, no rebate is given and if it exceeds the fixed price (which has actually occurred), corn starch producers pay an export levy.

The export rebate is based on the quantity of corn required to produce 100 kilos of starch. The E.E.C. uses a ratio of 161:100.

Using world market price from the previous example we arrive at the following example of an export rebate.

Fixed price of corn	Fls. 24.62 per 100 kilos
World market price	Fls. 20.20 per 100 kilos
	Fls. 4.42 per 100 kilos

Export rebate 1.61 x Fls. 4.42 = Fls. 7.12

It should be noted that the export rebate is established in Brussels and calculated by taking the average difference in the first 25 days of the previous month. If in the current month heavy fluctuations occur in world corn prices an adjustment can be made. Thus, the export rebate for the month of February 1972 for corn starch was set at Fls. 6.67 per 100 kilos.

Using the E.E.C. principle that "starch is starch", Dutch potato starch producers receive the same production and export restitutions as do corn starch manufacturers. Manufacturing costs in corn starch and potato starch industries are considered to be identical. The production restitution for potato starch production is established at the beginning of the year and remains fixed for that year because potato starch is a seasonal business. The restitution for the 1971-72 year was set at Fls. 3.28 per 100 kilos of starch potatoes. To arrive at a concrete amount for the production restitution on potato starch, the formula was established that 535 kilos of starch potatoes at 17 per cent starch yield 100 kilos of starch. The restitution payment is paid to the farmer directly. The approximate price of potatoes in February was Fls. 8.10 per 100 kilos (17 per cent starch) delivered at factory consisting of Fls. 3.28 production restitution and Fls. 4.82 paid by the processor. The export rebate on potato starch is equal to that given on corn starch (Fls. 6.67 per 100 kilos).

The potato starch industry in Canada has remained very small accounting for less than 5 per cent of total starch production; the number of producers has actually declined. A brief comparison

and explanation of the raw material costs between Canada and the Netherlands for corn and potatoes may be useful. The following example illustrates the raw material costs for corn and potatoes in each country.

	Netherlands[3]	Canada
Price for potatoes per hundred pounds	$0.68	$0.27
Price of corn per bushel	1.95	1.20
Cost of potatoes required to produce 100 pounds of starch	3.64	2.73
Cost of corn required to produce 100 pounds of starch	5.61	3.45

The number of pounds of raw material required to produce 100 pounds of starch was calculated as 161 pounds of corn for both countries and as 535 pounds of potatoes for the Netherlands and as 1,000 pounds of potatoes for Canada. The Canadian potato starch industry has not expanded in spite of lower raw material costs. The reason for this is the limited volume of potatoes available at these low prices and the lack of continuity in supply. No potatoes in Canada are produced solely for the starch industry. Only cull potatoes and "field-run" potatoes are processed into starch in Canada. The only exception to this occurs during periods of over-production when government programs are implemented to divert potatoes into starch production. This situation contrasts with that in the Netherlands where special high starch content varieties of potatoes are produced on a large scale solely for processing by the starch industry.

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[3] $ CDN = Fls. 3.21

APPENDIX C

Tariffs on Starches and Starch Derived Products in Selected Countries

Canadian tariffs on starches, glucose and dextrose are as follows (in cents per pound):

	British Preferential Tariff	Most Favoured Nation	General Tariff
Potato starch and potato flour	1.00	1.50	2.00
Starch of flour of sago, cassava or rice	0.75	1.00	1.25
Starch, and all preparation having the quality of starch, n.o.p.	1.00	1.00	2.00
Dextrine, and combinations or preparations of starch and dextrine without admixture of foreign material, n.o.p.	0.50	1.00	1.25
Combinations or preparations of starch and dextrine with admixture of foreign material, n.o.p. when mixed with cold water, does not form any adhesive paste.	1.00	1.00	2.50
Glucose or grape sugar, glucose syrup.	0.75	1.50	1.50

Most starch imports enter Canada under the most favoured nation tariff.

C-2

European Economic Community tariffs on starches, glucose and dextrins are as follows:

Tariff Heading	Description of goods	Duty (Can. cents per lb.) Variable Levy (Third Countries) Feb. 1, 1972[1]	% plus variable component[2]
11.08A	Starches:		
	I. Maize starch	1.61	--
	II. Rice starch	1.52	--
	III. Wheat starch	2.09	--
	IV. Other cereal starches	1.61	--
	V. Potato starch	1.61	--
11.09	Gluten and gluten flour, roasted or not:		
	A. Obtained from soft wheat	9.22	--
	B. Other	9.22	--
17.02B	Glucose and glucose syrups		
	I. Glucose in the form of white crystalline powder, whether or not agglomerated	4.33	--
	II. Other	3.34	--
19.04	Tapioca and sago; tapioca and sago substitutes obtained from potato or other starches	--	10% + 1.26
35.05	Dextrins and dextrin glues; soluble soluble or roasted starches; starch glues:		
	A. Dextrines; soluble or roasted starches	--	14% + 1.26
	B. Glues made from dextrin or from starch, containing by weight of those materials		
	I. Less than 25%	--	13% + 0.32
	II. 25% or more but less than 55%	--	13% + 0.64
	III. 55% or more but less than 80%	--	13% + 1.01
	IV. 80% or more	--	13% + 1.26

Source: Journal Official des Communautés Européenes

[1]Variable levies are established monthly. The figures shown have been converted to Canadian cents per pound from E.E.C. units of account (US dollars) per 100 kg.

[2]Variable component levies are established quarterly and are published in the currency of each E.E.C. member country. These levies are approximately the same when converted to Canadian cents per lb. and thus they are shown in Canadian cents per lb.

United Kingdom tariff rates on starches and glucose are as follows (Canadian cents per pound - £ 1 = Canadian $2.615).

	Full	Commonwealth	EFTA
Starches			
Maize and milo	7¼%	Free	7¼%
Farina	Free	Free	Free
Rice, Millett and Buckwheat	0.98	Free	0.98
Sago	5%	Free	5%
Manioc (cassava)	Free	Free	Free
Other	10%	Free	10%
Glucose			
Solid	0.48	Free	0.48
Liquid	0.35	Free	0.35
Dextrine and dextrine glues, soluble or roasted starches starch glues	10%	Free	Free

Note: The United Kingdom's entry into the EEC will eventually result in the adoption of the EEC's Common External Tariff.

Japanese tariffs on starches and gluten are as follows.

	General Rate of Duty
Wheat starch	23%
Corn starch	25%
Manioc starch and sago starch	25%
Other	25%
Gluten and gluten flour roasted or not	25%

Australian tariff rates on starches and glucose are as follows (Canadian cents per pound - Australian $1 = Canadian $1.1980).

	General	Preferential
Potato Starch	Free	Free
Maize Starch	1.68	1.08
Other	3.00	1.44
	Primage 10%	Primage 5%
Glucose or Glucose syrups	1.80	0.72

United States tariff rates on starches, dextrose and glucose are as follows (U.S. cents per pound):

Cassava flour and starch, and tapioca	Free
Arrowroots and sago flours and starches	Free
Potato Starch	2.5
Other Starches	0.7
Dextrine and soluble or chemically treated starches	3.0
Dextrose and Dextrose Syrup	1.6

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